TALLINNA TEHNIKAÜLIKOOL
TALLINN UNIVERSITY OF TECHNOLOGY

UBIK S350 OPTIVERTER®
PERFORMANCE TESTS

Power Electronics Group | Tallinn University of Technology
Department of Electrical Power Engineering & Mechatronics

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POWER GROUP ELECTRONICS

Acknowledgments

UBIK Solutions Ltd in cooperation with the Power Electronics Group of Tallinn University of Technology have developed and brought to market OPTIVERTER®, a revolutionary power conversion technology for residential and small-to-medium commercial photovoltaic installations.

Within cooperation between UBIK Solutions and Tallinn University of Technology, Department of Electrical Power Engineering & Mechatronics, UBIK Solutions ordered the Power Electronics Group to execute several tests to compare the first commercial product, S350 OPTIVERTER® to other competing microinverters. The test runs where performed in standard test conditions and in permanently grid-tied installation settings outdoors where the impact of shading on the system performance was measured and evaluated. The report describes the executed activities and main findings.

TALLINNA TEHNIKAÜLIKOOL
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Dr. Dmitri Vinnikov

Head of Power Electronics Group

Tallinn University of Technology, Estonia

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Abbreviations and Units

PV - Photovoltaic

DC – Direct Current

AC - Alternating Current

MPP – Maximum Power Point

MPPT - Maximum Power Point Tracking

STMPPT – shade-tolerant maximum power point tracking

STC - Standard Test Conditions

CEC - California Energy Commission

THD - Total Harmonic Distortion

TUT – Tallinn University of Technology

W – Watt

kW – kilowatt

kWh – kilowatt hour

EU – European Union

Executive Summary

UBIK Solutions Ltd. has introduced a brand new, innovative and patented energy conversion solution for module level power electronics (MLPE) solar industry, the OPTIVERTER® Technology.

The OPTIVERTER® Technology combines the key advantages of the popular PV microinverters and PV power optimizers. This allows direct AC connectivity of the PV module, highest possible energy harvest efficiency, inherent safety and system reliability. The first offering is the 350W UBIK S350 OPTIVERTER®.

Several test runs where performed in standard test conditions (STC) and in permanently grid-tied installation settings outdoors, where UBIK S350 OPTIVERTER® performance was compared with two competing microinverters, hereinafter referred to as “premium” and “budget”.

Current report presents the performance tests of typical residential rooftop photovoltaic (PV) modules and evaluates the impact of shading on the system performance. Comparison tests were executed, data collected and analyzed from Power Electronics lab in TUT and from one of the test sites located in Pirita, Tallinn, Estonia

All the tests, analysis and conclusions were carried out by Tallinn University of Technology, the Department of Electrical Power Engineering and Mechatronics, Power Electronics Group by the following team:

- Project manager / supervisor: Dr. Dmitri Vinnikov (Leading researcher);
- Testing engineer: Dr. Tanel Jalakas (senior researcher);
- Data analyst: Roman Kosenko (junior researcher).

The performed test runs revealed that the design of the OPTIVERTER® provides safe and efficient means of converting DC power to AC. Compared with the benchmarked competitors, the inclusion of the Shade-Tolerant-Maximum Power Point Tracking (STMPPT) increases the efficiency of the OPTIVERTER® in multiple operational environments such as shading. Recently UBIK S350 OPTIVERTER® is the only microinverter in the world which offers the STMPPT functionality.

The STMPPT is an ability of the PV power conditioning system to effectively harvest energy from a partially-shaded PV module. PV modules in urban conditions often experience partial shading effects, which could be caused by various obstructions including trees, roof top structures and neighboring buildings, clouds, dust, bird droppings, haze, falling leaves, snow, etc. Different orientations and tilts of the PV module can lead to different shading shapes. These can be large or small spots, dappled or hard edged, linear or irregular in nature. Some shading types can cover a single cell of a module and some can cover an entire module thus resulting in different output voltages and powers of the PV module.

The OPTIVERTER® outperforms premium and budget competitor microinverters. Thanks to the applied STMPPT functionality, the UBIK S350 harvests up to 33% more energy than compared ones with light and medium shading.

Background & Aims

In PV systems, it is practically impossible to completely avoid shading, which can be caused by trees, chimneys, satellite dishes etc. In these systems, partial shading losses are estimated to result in a 5%-25% annual energy loss.

Shading of any part of PV array will reduce its output. Clearly, the output of any shaded cell or module will be lowered in correlation with the reduction in light falling on it. However, in systems with traditional string inverters, unshaded cells or modules may also be affected by the shade.

For example, if a single module in a series string is partially shaded, its current output will be reduced, and this may dictate the operating point of all the modules in the string. Alternately, the shaded module may be bypassed, leading this module to stop producing power entirely (Fig. 1). If several modules are shaded, the string voltage may be reduced to a value lower than the inverter's minimum operating point, causing that string to produce no power.

Fig. 1. Conditions resulting in partial shading of the residential PV installations

In partial shading conditions the shaded substring(s) are usually bypassed by the integrated bypass diodes, resulting in less cells available for power production. This causes a drop in the output voltage of the PV module. If one or two substrings are shaded, the module can potentially lose one or two thirds of its output voltage. For example, in a common 60-cell module with an MPP voltage of 33-37 V one and two shaded substrings will shift the MPP voltage down to 24 V and 15 V, respectively. Fig. 2 illustrates the resulting I-V curve of a 60-cell PV module with corner shading of 15%, where the distinct global and local power maximum can be observed due to the bypassed substring.

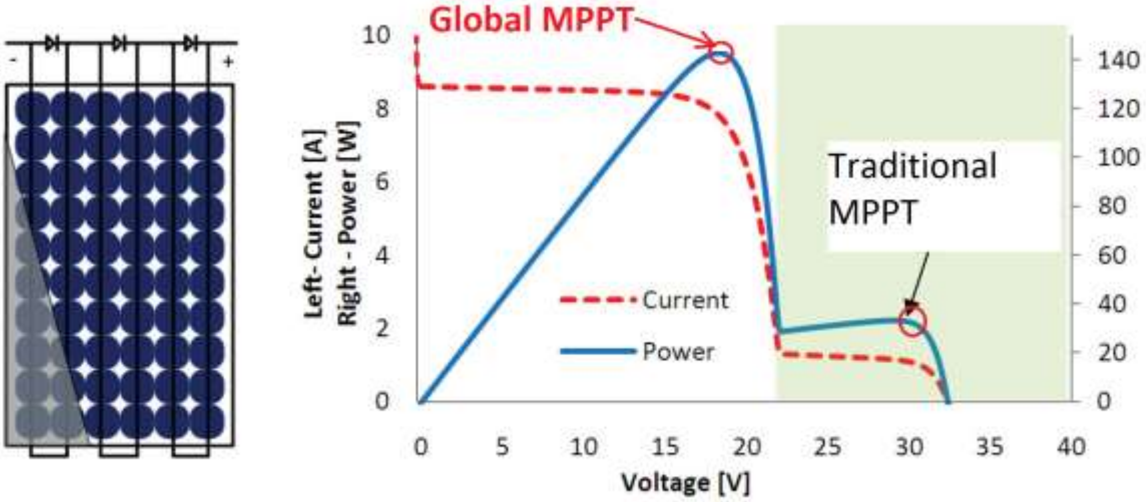


Fig. 2. Example of partial the shading of the 60-cell PV module and its impact on the output parameters (shaded substring has irradiance of 150W/m^2 and the other two - 1000 W/m^2)

UBIK Solutions Ltd has introduced a brand new, innovative and patented energy conversion solution for module level power electronics (MLPE) solar industry, the OPTIVERTER® Technology.

The main competitive advantage of OPTIVERTER® is the highest possible energy harvest efficiency, in other words its ability to extract the maximum amount of available power from the PV module. It also means that partial shading which is the main factor in production decrease will not be an issue with solar panels any more. This was achieved by the combination of the STMPPT functionality (also known as the Global MPPT) with the maximized operating power of the converter.

All modern PV microinverters have a relatively narrow MPPT range typically starting from 22 V and, therefore, could track only the local power maximum. For example, the premium competitor microinverter has an MPPT voltage range of 27…39 V, which means that if a module's voltage decreases below 27V, this microinverter would not be able to track MPP of the PV module.

Rather, it would de-MPP the PV module to maintain a high enough voltage to continue to operate in an unoptimized working point. Thanks to the state-of-the-art impedance source resonant converter topology and advanced multimode control algorithm, the OPTIVERTER® has an ultra-wide MPPT range similar to that of the non-isolated PV power optimizers.

Test objectives

1. To compare the power conversion efficiency and energy harvest of the S350 OPTIVERTER® versus competitors under STC environment;
2. To compare the existing power control functions of the OPTIVERTER® (STMPPT) versus competitors under shaded conditions;
3. To propose the additional third-party testing scope for further development to improve OPTIVERTER® existing power control functions, identify potential issues or modifications required.

Testing environment & benchmarked systems

Comparison tests were executed, data was collected and analyzed from Power Electronics (PE) laboratory in Tallinn University of Technology (TUT) and from one test sites located in Tallinn, Estonia:

1) STC environment established and all tests executed by the Power Electronics Group in TUT. PV modules output power incl. shading was emulated by means of the Solar Array Simulator (SAS) Agilent E4360. Exact PV module characteristics of 250W, 60 cell NAPS Saana 250 SP3 MAW and 305W, 72-cell PV Module Trinasolar TSM-PD14-305 were reproduced in SAS;
2) Pirita 1 (Fig. 3): located in Pirita harbor, with two 250W, 60 cell PV modules NAPS Saana 250S P3 MAW; permanently grid-tied with local distribution grid.

Fig. 3. Pirita 1 permanent grid-tied installation with two Naps Saana 250 SP3 MAW PV modules (2x1 substring shaded)

The UBIK S350 OPTIVERTER® general data and the benchmarked microinverters technical specifications are listed in Annex 1.

Performance tests performed in PE lab. of TUT

Comparison of the efficiency of microinverters

Static efficiency measurements were performed on 6. April 2017 in TUT power electronics laboratory. The overall results, under different power levels, are presented in Fig. 4.

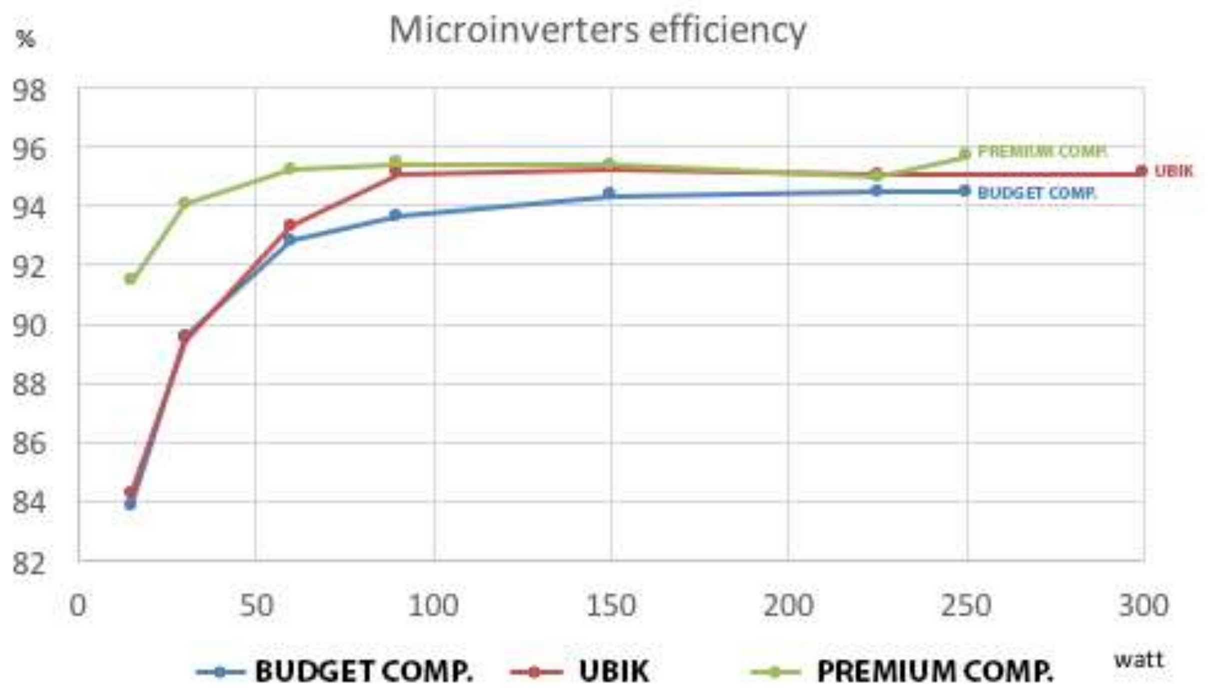


Fig. 4. UBIK S350 OPTIVERTER® efficiency curve compared vs premium and budget competitors

As the figure shows, with S350 model, UBIK has reached already competitive efficiency curve without fine tuning at low power region (from 0-100 W). Also it was shown that both, premium and budget competitor microinverters do not reach their peak efficiencies, stated in their datasheets.

At nominal power level - 250W, premium competitor microinverter actual efficiency figure is 95.7% (96.5% presented in datasheet) and 94% for budget one (95% in datasheet). At 250W, S350 showed 95.1%. Efficiency will be improved during continuous software development up to up to around 96%.

Benefits of Shade-Tolerant MPPT

The partial shading scenario of the typical residential rooftop PV installation based on the 60-cell PV module NAPS Saana 250 SP3 MAW with the STC power of 250 W was emulated by the Solar Array Simulator (SAS) Agilent E4360 with the pre-programmed I-V curve of the partially shaded PV module, i.e. when one substring is shaded (200 W/m^2) and the rest two are under STC (1000 W/m^2). Next, the static MPPT efficiency (i.e. the ability of the MPPT to find and hold the maximum power point) and power captured from the PV module were compared.

The experimental results of the static MPPT efficiency and power captured from the 60 cell PV module NAPS Saana 250 SP3 MAW under the partial shading conditions are presented in fig. 6. It is the evident from fig. 5 (a) that premium competitor microinverter fails to perform the MPPT in partial-shading conditions (MPPT stucks at local maximum, static MPPT efficiency is 35.8%, power captured from the PV module is limited by 57 W). In the same operating conditions, the UBIK S350 OPTIVERTER® captures all available power from the PV module (MPPT quality 99.8%, captured power is 160 W).

(a) (b)

Fig. 5. Comparison of static MPPT efficiency and power captured from the 60-cell PV module NAPS Saana 250 SP3 MAW under the partial shading conditions. Premium competitor on the left, UBIK on the right.

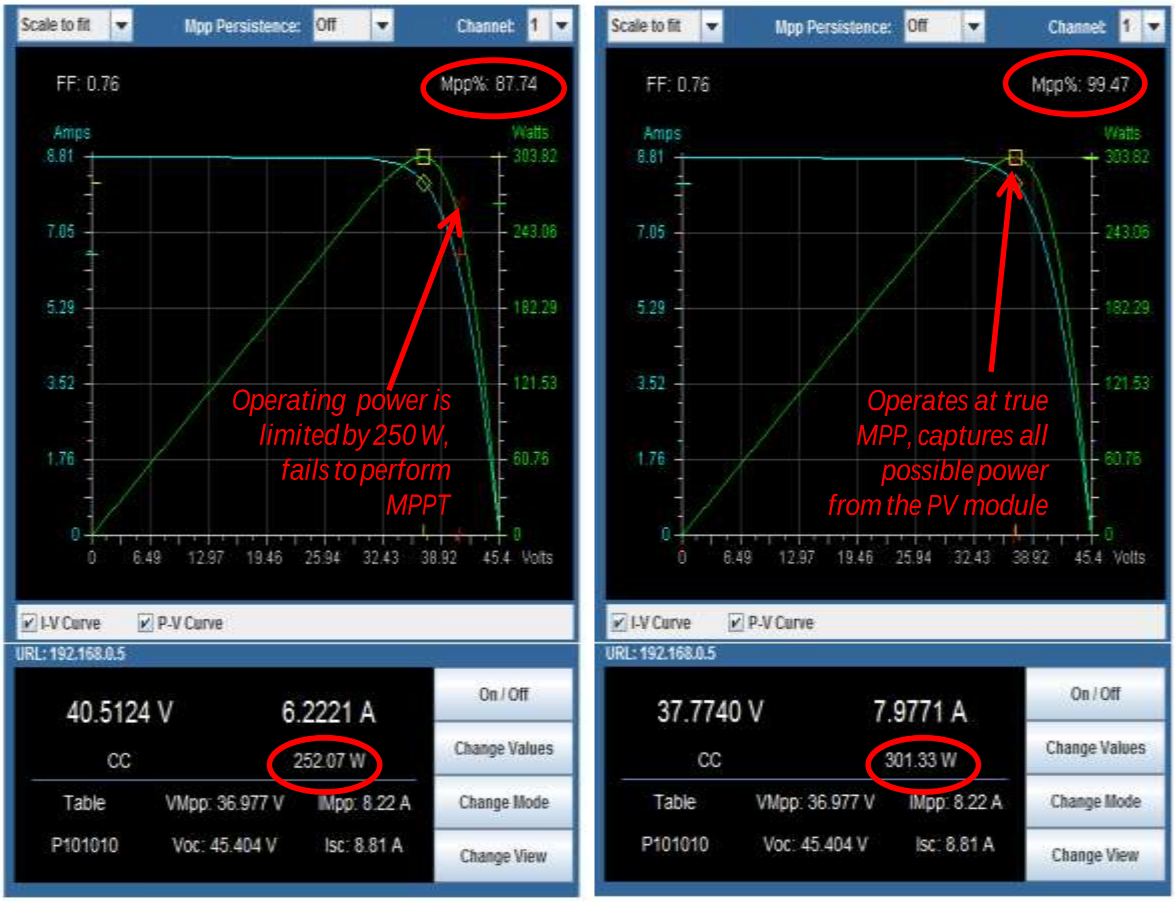
Finally, it can be concluded that thanks to its advanced time-adaptive seamless PV curve sweep MPPT the UBIK S350 OPTIVERTER® features more than 250% better energy harvest (160 W vs 57 W) in the given partial shading conditions (Premium competitor has the partial-shading loss of over 100 W). Recently S350 is the only microinverter in the world which offers the STMPPT functionality, even in the case of two shaded substrings.

Operation with High-Power 72 cell PV module

In this test the resulting advantages of the maximized operating power available from UBIK S350 OPTIVERTER® are demonstrated and compared with the classical approach implemented by the premium competitor microinverter. The typical residential rooftop PV installation based on the 72-cell PV Module Trinasolar TSM-PD14-305 with the STC power of 305 W was emulated by the Solar Array Simulator (SAS) Agilent E4360 with the pre-programmed I-V curve of the PV module operating at the STC, i.e. uniform irradiation of the PV module (1000 W/m2).

Next, the static MPPT efficiency (i.e. the ability of the MPPT to find and hold the maximum power point) and power captured from the PV module were compared.

The experimental results of the static MPPT efficiency and power captured from the PV module Trinasolar TSM-PD14-305 under STC are presented in fig. 6. It is seen from fig. 6 (a) that the premium competitor fails to perform MPPT because of the "power clipping" issue (MPPT performance was affected by the output power limitation, static MPPT quality 87.7%, power captured from the PV module is 252 W, power shortage 50 W). In contrary to that the UBIK S350 OPTIVERTER® captures all available power from the PV module (static MPPT quality 99.5%, captured power 301 W).



(a) *(b)*

Fig. 6. Comparison of static MPPT efficiency and power captured from the 60-cell PV module Trinasolar TSM-PD14-305 under the partial shading conditions. Premium competitor on the left, UBIK on the right.

Finally, it can be concluded that thanks to 40% increased operating power the S350 can work with all existing 60- and 72-cell PV modules with the nameplate powers up to 350 W and open cell voltages up to 60 V.

Operation with High-Power 72-cell PV module under partial shading conditions

In this test the resulting advantage of the maximized output power in combination with the shade-tolerant MPPT (or Global MPPT) control available from the UBIK S350 OPTIVERTER® are demonstrated and compared with the classical approach implemented by the premium competitor microinverter.

The partial shading scenario of the typical residential rooftop PV installation based on the high-power 72-cell PV module Trinasolar TSM-PD14-305 with the STC power of 305 W was emulated by the Solar Array Simulator (SAS) Agilent E4360 with the pre-programmed I-V curve of the partially shaded PV module, i.e. when one substring is shaded (200 W/m^2) and the rest two are under STC (1000 W/m^2). Next, the static MPPT efficiency (i.e. the ability of the MPPT to find and hold the maximum power point) and power captured from the PV module were compared. The shading losses are estimated to result in a 5-25% of annual energy losses.

The experimental results of the static MPPT efficiency and power captured from the 72-cell PV module Trinasolar TSM-PD14-305 under the partial shading conditions are presented in fig. 7. It is seen from Fig. 7 (a) that the premium microinverter competitor fails to perform the MPPT in partial shading conditions (MPPT stucks at local maximum, static MPPT quality 35.7%, power captured from the PV module is 70 W). At the same operating conditions, the UBIK S350 OPTIVERTER® captures all available power from the PV module (MPPT quality 99.8%, captured power 195 W).

(a) *(b)*

Fig. 7. Comparison of static MPPT efficiency and power captured from the 72-cell PV Module Trinasolar TSM-PD14-305 under the partial shading conditions. Premium competitor on the left, UBIK on the right.

Performance tests in outdoor environment

Test run 1

- Test site: Pirita 1, Tallinn
- Date: March 22, 2017
- Weather conditions: overcast
- Test scenario: UBIK S350 vs. premium competitor; one substring shaded.

Main findings: The power production is presented in fig. 8. under very cloudy environment STMPPT functionality shows its best potential, +33.3% daily energy harvest compared to the premium competitor (0.186 kWh vs. 0.134 kWh).

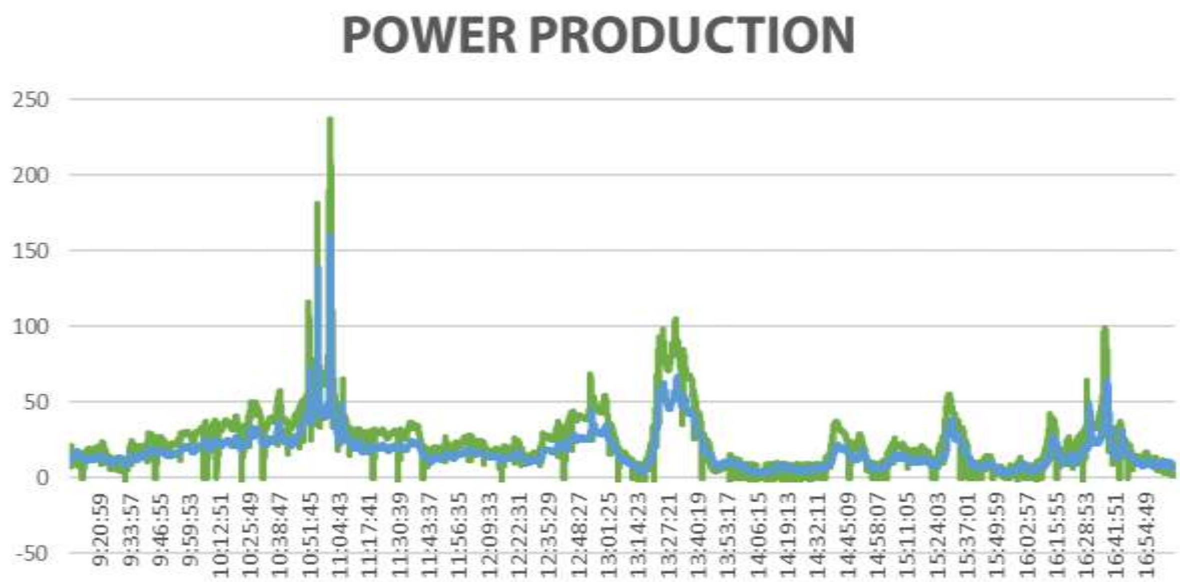


Fig. 8. UBIK S350 OPTIVERTER® (green) vs. premium competitor (blue) production on March 22, 2017

Device	Cumulative daily power production	Energy harvest difference
UBIK S350 OPTIVERTER®	186.20 Wh	+33.33 %
Premium competitor	139.70 Wh	-

Test run 2

- Test site: Pirita 1
- Date: March 23, 2017
- Weather conditions: sunny
- Test scenario: UBIK S350 vs. premium competitor; one substring shaded.

Main findings: The power production is presented in fig. 9. STMPPT functionality performs well, +32.5% daily energy harvest compared to the premium competitor (1.318 kWh vs. 0.994 kWh).

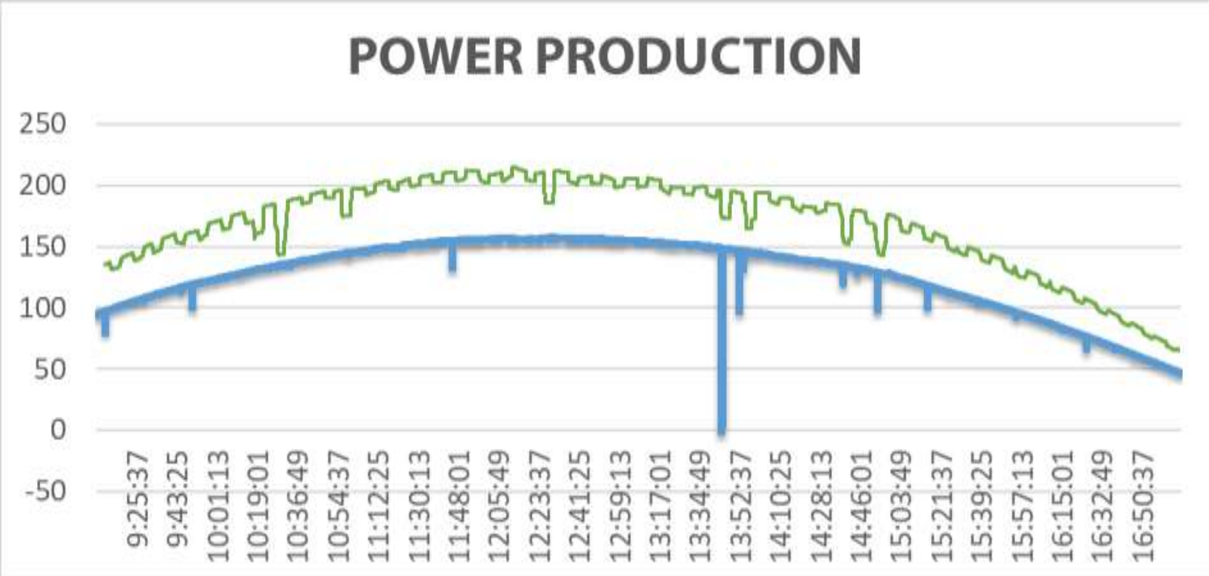


Fig. 9. UBIK S350 OPTIVERTER® (green) vs. premium competitor (blue) production on March 23, 2017

Device	Cumulative daily power production	Energy harvest difference
UBIK S350 OPTIVERTER®	1317.62 Wh	+32.5 %
Premium competitor	993.88 Wh	-

Test run 3

- Test site: Pirita 1
- Date: March 26, 2017
- Weather conditions: overcast
- Test scenario: S350 vs. budget competitor; one substring shaded.

Main findings: The power production is presented in fig. 10. Again, UBIK S350 STMPPT performs very well under rainy weather, +30% daily energy harvest compared to budget competitor (0.155 kWh vs. 0.119 kWh).

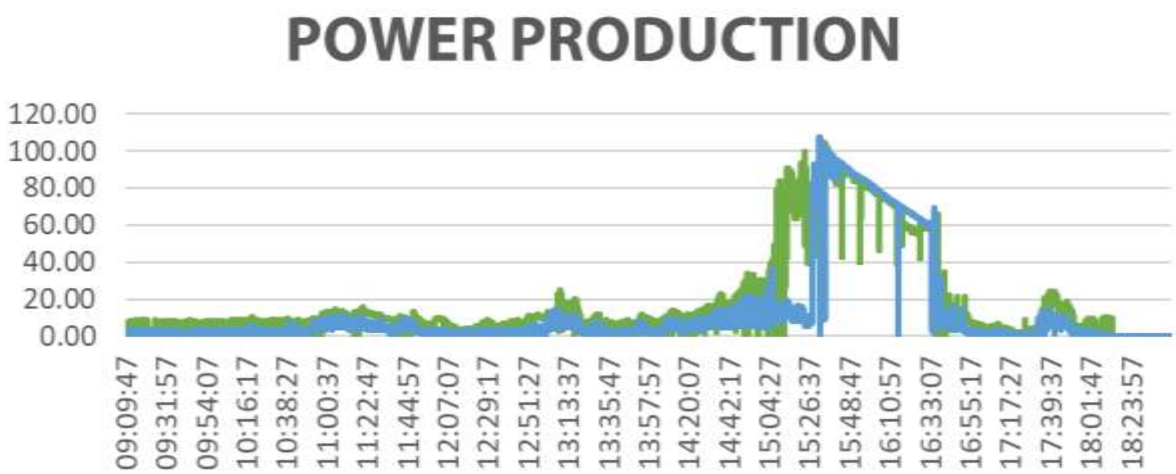


Fig. 10. UBIK S350 OPTIVERTER® (green) vs. budget competitor (blue) production on March 23, 2017

Device	Cumulative daily power production	Energy harvest difference
UBIK S350 OPTIVERTER®	155 Wh	+30 %
Budget competitor	119.47 Wh	-

Test run 4

- Test site: Pirita 1
- Date: April 20, 2017
- Weather conditions: sunny, clouds in the afternoon
- Test scenario: S350 vs. budget competitor; one substring shaded

Main findings: The power production is presented in fig. 11. STMPPT functionality performs well, +73% daily energy harvest compared to the budget competitor (0.534 kWh vs. 0.144 kWh).

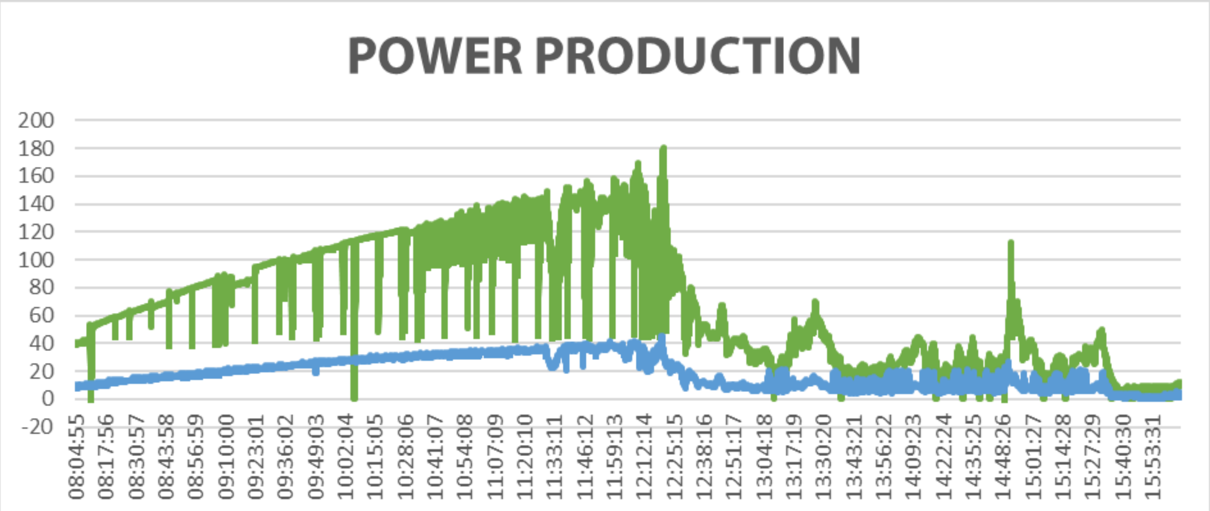


Fig. 11. UBIK S350 OPTIVERTER® (green) vs. budget competitor (blue) production on April 20, 2017

Device	Cumulative daily power production	Energy harvest difference
UBIK S350 OPTIVERTER®	534.28 Wh	+73 %
Budget competitor	143.97 Wh	-

Key findings

The performed test runs revealed that the design of the OPTIVERTER® provides safe and efficient means of converting DC power to AC. Compared with the benchmarked competitors, the inclusion of the Shade-Tolerant-Maximum Power Point Tracking (STMPPT) increases the efficiency of the OPTIVERTER® in multiple operational environments such as shading. The STMPPT has an ability of the PV power conditioning system to effectively harvest energy from a partially-shaded PV module.

Outdoor tests indicate that UBIK S350 OPTIVERTER® outperforms both benchmarked competitors and it does not matter if there is environmental shading or just bad weather. The average energy harvest under partial shading conditions was measured at least 30% higher than that of the compared microinverters.

Presented figures are insufficient to draw any definitive conclusions. But they show that UBIK S350 OPTIVERTER® is technically strong product and implemented STMPPT functionality enables to raise entire PV system capability. Long-term measurement logs must be collected, different test scenarios implemented and analyzed along with establishing new test site establishments.

Benchmarked device	Weather conditions	UBIK S350 OPTIVERTER® Energy harvest difference
Premium competitor	overcast	+33.33 %
	sunny	+32.5 %
Budget competitor	overcast / rainy	+30 %
	sunny	+73 %

Annexes

Annex 1 – Datasheet comparison

Device	UBIK S350 OPTIVERTER®	Premium microinverter comp.	Budget microinverter comp.
Compatibility	All 60-cell and 72-cell PV modules	60-cell PV modules	60-cell and 72-cell PV modules
Maximum PV module STC power	350 W	310 W	300 W
Minimum/Maximum input voltage	7 / 60 VDC	16 / 48 VDC	18 / 54 VDC
MPPT voltage range	8 - 60 VDC	27 – 39 VDC	28 – 42 VDC
Nominal output voltage	230 VAC	240 VAC	230 VAC
Max continuous input current	11 A	10 A	9.5 A
Output frequency	50 Hz	50/60 Hz	50/60 Hz
Enclosure	IP67	IP67	IP65
CEC efficiency	95 %	96.5 %	95 %
Static MPPT efficiency	99.5 %	99.4 %	99.9 %
Power factor	> 0.99	> 0.95	> 0.99
Communication:	Wi-Fi (IEEE 802.11 b/g/n)	Powerline	Powerline
Dimensions (W x H x D)	216 mm x 173 mm x 48 mm	171 mm x 173 mm x 30 mm	163 mm x 163 mm x 27 mm
Weight	2.2 kg	1.6 kg	1.5 kg
Ambient temperature	-40°C ... +65°C	-40°C ... +65°C	-40°C ... +65°C
Cooling	Natural convection	Natural convection	Natural convection