

# A YIELD COMPARISON BETWEEN DC OPTIMIZED SYSTEMS AND CONVENTIONAL PV SYSTEMS USING FRONIUS INVERTERS

White Paper

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Gender-specific wording refers equally to female and male form.

## ABSTRACT

In this paper two randomly chosen systems, where DC optimized systems meet conventional string inverters under non-laboratory comparable conditions (homogeneous shade vs. unshaded, same orientation, same system size, and comparable string design) have been compared in terms of yield.

The findings show that there is no extra yield to be expected from so called DC optimized system in direct comparison with conventional string-inverters after a 6 months observation period. There are a few days where DC optimized systems have shown extra yield which occurs in periods of poor irradiation in winter due to snow cover. The additionally gained kWhs do not impact the annual yield in a way that it would justify the added effort in installation, commissioning and added cost of optimizers. A brief cost analysis shows cost advantages of standard string inverter systems.

Furthermore it was investigated that there is no advantage of DC optimized systems in unshaded or even partly shaded single-string systems. This is due to the outstanding shade impact mitigation algorithm called Fronius Dynamic Peak Manager (DPM) that Fronius inverters offer.

## INTRODUCTION

Module Level Power Electronics (MLPE) are becoming more and more popular in some regions of the world. However, traditional string-inverters are still used in the majority of installations worldwide and there are significant reasons for that.

This paper investigates the yield of two different PV systems where the same part of modules are connected to Fronius SnapINverter and inverters from an MLPE manufacturer that offers a closed system consisting of optimizers and inverters. The systems have the same orientation, location and same size in order to determine if there is a real advantage in terms of extra yield achievable with so called DC optimized systems.

## SCOPE AND METHODOLOGY

Based on a theoretical analysis of MPP-tracking and inverter efficiency the two demonstration systems are introduced by a day-to-day yield comparison between the Fronius standard string inverter and the proprietary DC optimized system. The data for the investigations comes from the official monitoring platforms Fronius Solar.web ([www.solarweb.com](http://www.solarweb.com)) and the competitor's.

Yield comparison on a monthly basis and after each observation period will be displayed in this paper.

## EFFICIENCY COMPARISON

The vendor offering the DC optimized system claims that the DC optimized system generates more energy, so one might think that the inverters must have a better efficiency than conventional inverters. Especially under the aspect that the DC-DC conversion stage has been sourced out to the modules, a system's efficiency is not represented by the inverters efficiency alone. The optimiser's efficiency need to be taken into account as well. The total efficiency in a system consisting of inverter and power optimizer is calculated according to the formula:

$$\eta_{Inv} \cdot \eta_{Opt} = \eta_{Total}$$

The following table shows a comparison between Fronius datasheet and the competitor's datasheets:

EFFICIENCY	FRONIUS SYMO 15.0-3-M	COMPETITOR 15KVA + DUAL MODULE OPTIMIZERS	COMPETITOR 15KVA + SINGLE MODULE OPTIMIZERS	FRONIUS PRIMO 6.0-1	COMPETITOR 6KVA + SINGLE MODULE OPTIMIZERS
$\eta_{max}$ <b>INVERTER</b>	98.1%	98.0%	98.0%	98.0%	97.6%
$\eta_{EU}$ <b>INVERTER</b>	97.8%	97.6%	97.6%	97.3%	97.4%
$\eta_{max}$ <b>OPTIMISER</b>		99.5%	99.5%		99.5%
$\eta_{weighted}$ <b>OPTIMISER</b>		98.6%	98.8%		98.8%
$\eta_{max}$	<b>98.1%</b>	<b>97.5%</b>	<b>97.5%</b>	<b>98.0%</b>	<b>97.1%</b>
$\eta_{EU,weighted}$	<b>97.8%</b>	<b>96.2%</b>	<b>96.4%</b>	<b>97.3%</b>	<b>96.2%</b>
<b>DIFFERENCE</b>		<b>-0.6%</b>	<b>-0.6%</b>		<b>-0.9%</b>
<b>DIFFERENCE</b>		<b>-1.6%</b>	<b>-1.4%</b>		<b>-1.1%</b>

Tabular 1: Comparison of inverter efficiency according to datasheets

As shown in the table above DC optimized system inverters efficiency doesn't reach the efficiency of the Fronius inverter. Taking the optimizers efficiency into calculation the weighted efficiency (EU-efficiency plus weighted optimizer efficiency) DC optimized systems seem to be up to 1.6% less efficient in equal conditions.

Efficiency alone is not a strong argument, mismatch mitigation on the modules side through distributed MPPT as well as accuracy and speed of MPPT can also have a significant effect in gaining extra yield.

The Fronius Dynamic Peak Manager<sup>2</sup> (DPM) not only offers best-in-class inverter integrated shade mitigation algorithm but also is able to adopt the speed of MPPT according to the environmental conditions. Under bright sunny conditions the MPPT is working slower than under cloudy conditions. Here the algorithm will automatically act faster in order to follow the more volatile PV-generator at a maximum dynamic MPPT accuracy and efficiency.

## INTRODUCTION OF THE TWO REFERENCE SYSTEMS

Two real-life PV installations (both located in Central Europe) have been used for a yield comparison. There is a commercial system called "System A" and a residential system called "System B". All data has been anonymized to protect the privacy of the owners granting access to their systems.

### "System A" – 17.16 kWp Fronius vs. 17.68 kWp optimized system

Commercial "System A" consists of multiple Fronius and competitor's inverters with a power class of 17kW. For the comparison two inverters with modules in the same orientation and next to each other on one single roof have been taken into account. This system consists of 260W modules in multiple strings. The optimized system in this power range has longer strings than standard inverters. Except for the string lengths the systems are equally oriented side-by-side on an unshaded south-facing roof.

### Characterization

- / **Observation period:** 6 months of comparable available monitoring
- / **Fronius inverter:** Fronius Symo 17.5-3-M, 3-phase, MPPT1: 2x22 panels, MPPT 2: 1x22 panels, total 3 strings with 17.16kWp, oversizing ratio  $IR^1 = 96\%$
- / **DC optimized system inverter:** Competitor inverter with 17kW, 3-phase, 2x34 modules with integrated optimizers, total of 2 strings with 17.68kWp, oversizing ratio  $IR^1 = 104\%$
- / **Additional info:**
  - / Roof tilt angle around  $30^\circ$ , south facing
  - / Geographical location: Austria
  - / Standard system for large rooftops
  - / No shade

In this scenario it can also be questioned whether the DC optimized system does gain more energy due to the fact that it can use longer strings and whether it is more advantageous to use optimizers in a multi-string system.

### “System B” – 5kWp Fronius vs. 5kWp DC optimized system

This system consists of a single string of 20 modules (each 250W) connected to each of the inverters. The string is mounted on a flat roof with same tilt, same orientation and same exposure to the sun. “System B” is characterized by strong homogeneous shade due to its location in a valley.

### Characterization

- / **Observation period:** 6 months of comparable available monitoring (September to February).
- / **Fronius inverter:** Fronius Symo 8.2-3-M, 3-phase, 20 modules in series (5kWp), 1 string,  $IR^1 = 60\%$
- / **DC optimized system inverter:** Competitor's inverter with 5kW, 3-phase, 20 modules with single module optimizers in series (5kWp), 1 string,  $IR^1 = 100\%$
- / **Additional Info:**
  - / Flat roof, south facing ( $10^\circ$  deviation towards east), module's tilt angle  $15^\circ$
  - / Geographical location: Switzerland
  - / System characterized by heavy shade on full system in the morning (until the sun breaks through)
  - / The additional installation effort to install (retrofit) the optimizers was about ~45min which reflects perfectly the ~2min per optimizer that the DC optimized system competitor states as an average.

The question in this situation is whether the single module optimizers system is able to gain significantly more energy before or when the sun is breaking through and does this extra energy pay off when looking at the system in total?

## POWER AND ENERGY IN THE COMPETITOR'S MONITORING PORTAL

The following results are based on the data of the monitoring platforms the two inverter manufacturers present. The energy yield was calculated by taking a 5 min power log-interval data. This data has then been compared with the aggregated energy yield the portal shows in the following graphs.

<sup>1</sup> IR ... Inverter ratio; Ratio between kWp module power to inverter's max. DC-power it can convert.

<sup>2</sup> Fronius Dynamic Peak Manager ... is a technology of a shading resistant multiple power point tracker

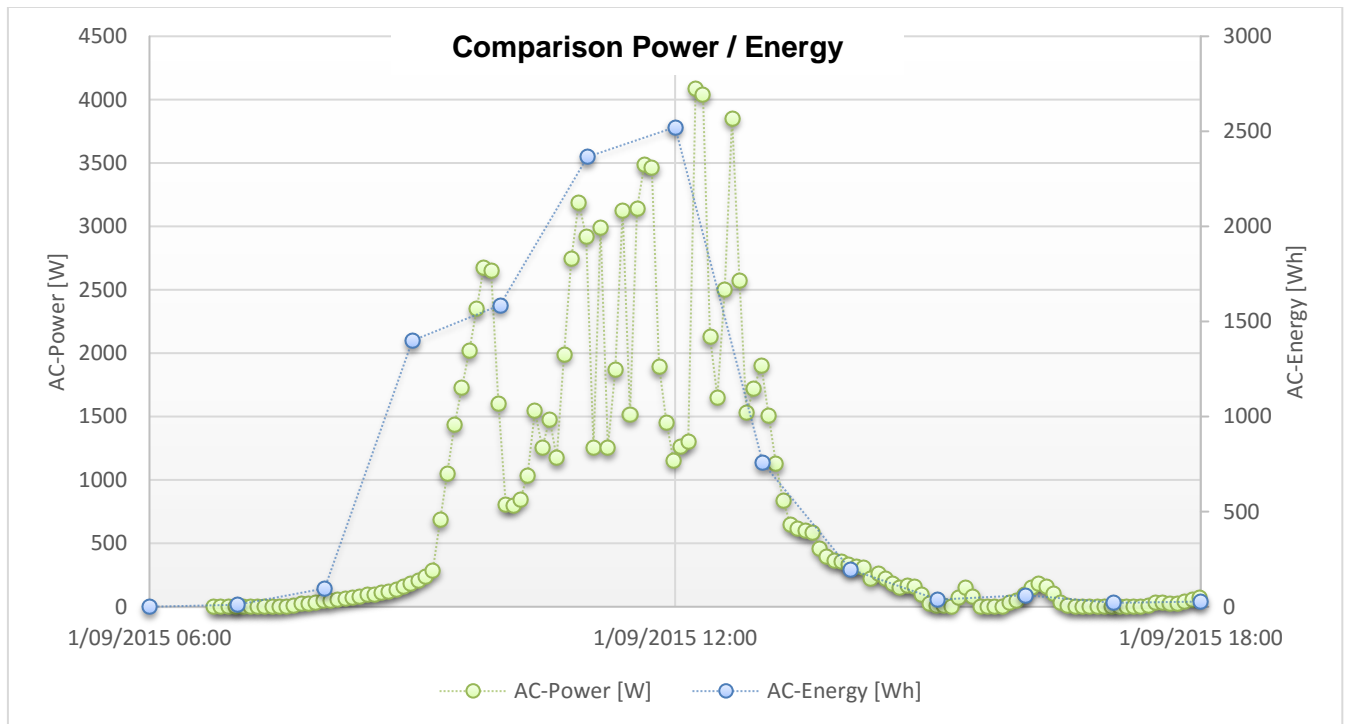


Figure 1: Exemplary day from the competitors monitoring portal to compare energy and power data given.

Figure 1 shows that there is no correlation between power and energy log points. For example in the above shown day, power values  $p_i$  have been converted into energy and summed up which is than a total yield of 8.74 kWh. But the monitoring portal on this specific day gives a yield of 9.08 kWh for the specific inverter - a deviation of 3.85%! Where this comes from cannot be explained.

Furthermore it was investigated that in general the energy data represented in the competitor's monitoring portal deviates from the total power of a monitoring period on average around +3%!

Since the curves shown in Figure 1 do not allow direct comparison the question arises, whether a non-comparability could be desired by nature. There is no mathematical way to convert one value into the other.

On the other hand, based on the Fronius Solar.Web portal data, calculation between yield and power set point can be done and there is absolutely no deviation between the manually calculated and the value in the stem-diagram the portal delivers.

To be clear on which values have been taken into this comparison we differentiate between "Calculated" (according to the calculation explained) and "Report" (according to the monitoring portal) energy values on the DC optimized systems side.

### System A – 5kWp shaded system

#### Yield comparison

Daily yield of the comparison period shows that the Fronius inverter achieved up to 1.24kWh (!) more yield and on average 554Wh on a single day. This is a total of extra yield of 9.1% during observation period which can be seen in Figure 2.

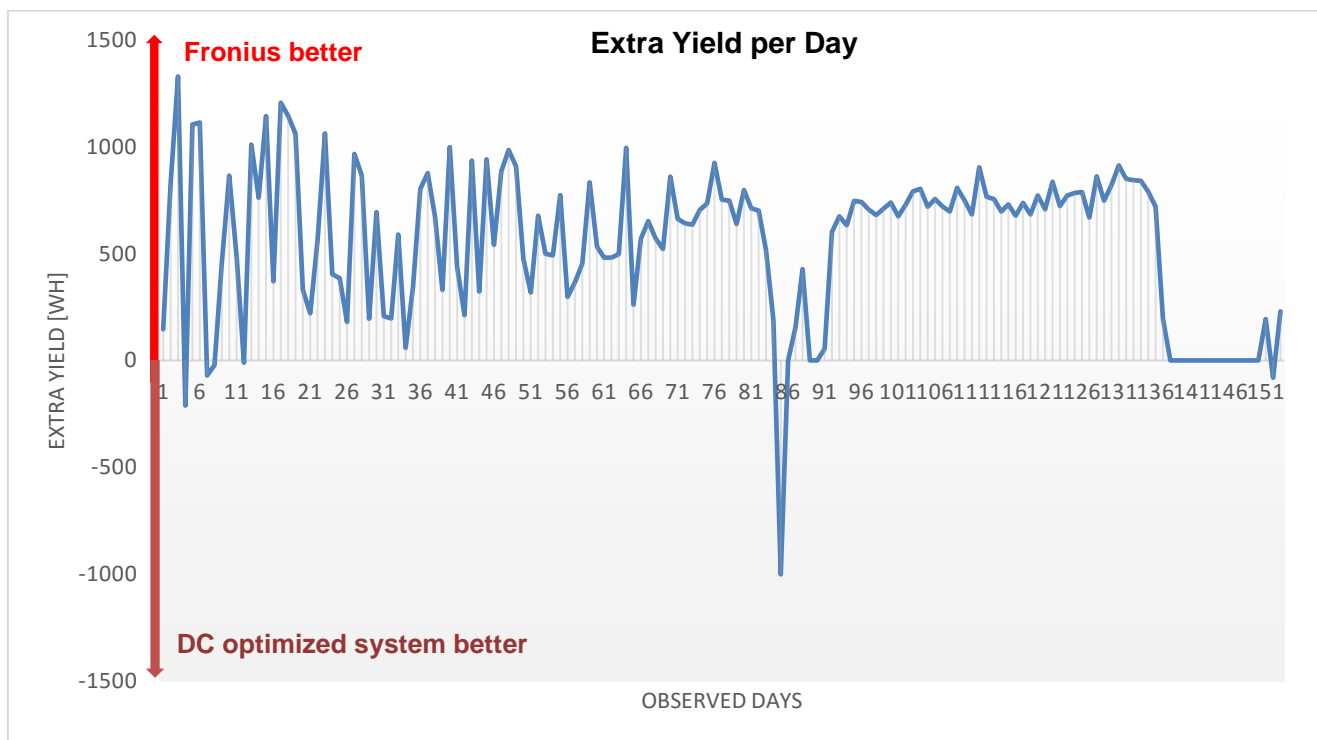


Figure 2: Day-to-day comparison of extra yield between Fronius and DC optimized system ("Report") values

Taking the manually calculated values of the DC optimized system into account leads to an actual average extra yield of the Fronius system of 731Wh per day or a total extra yield of 12.4% during the observation period. Fronius output is higher almost all days but in the graph one spike can be found showing that the DC optimized system produces more energy than the Fronius system. It is further investigated in the time-series shown below in Figure 3.

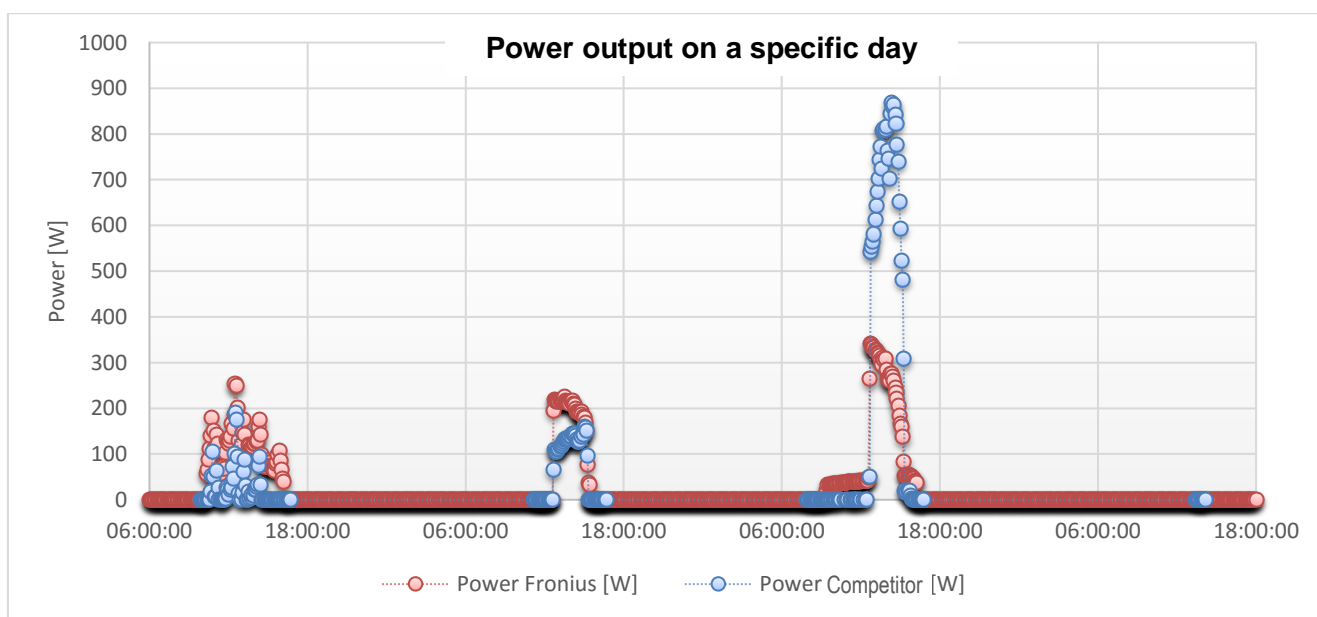


Figure 3: Analysing the worst performing day (#85) of the Fronius inverter

What exactly happened on that specific day (third day in the figure above) cannot be clearly reproduced but there are indications of a period of snowfall in winter. Snow cover on PV modules is a very stochastic phenomenon that can lead to deviations in yield even comparing non-DC optimized systems and it can be seen as an exception. For overall yield amongst a year, these random days do not impact the yield and does not justify any extra investment in a DC optimized system.

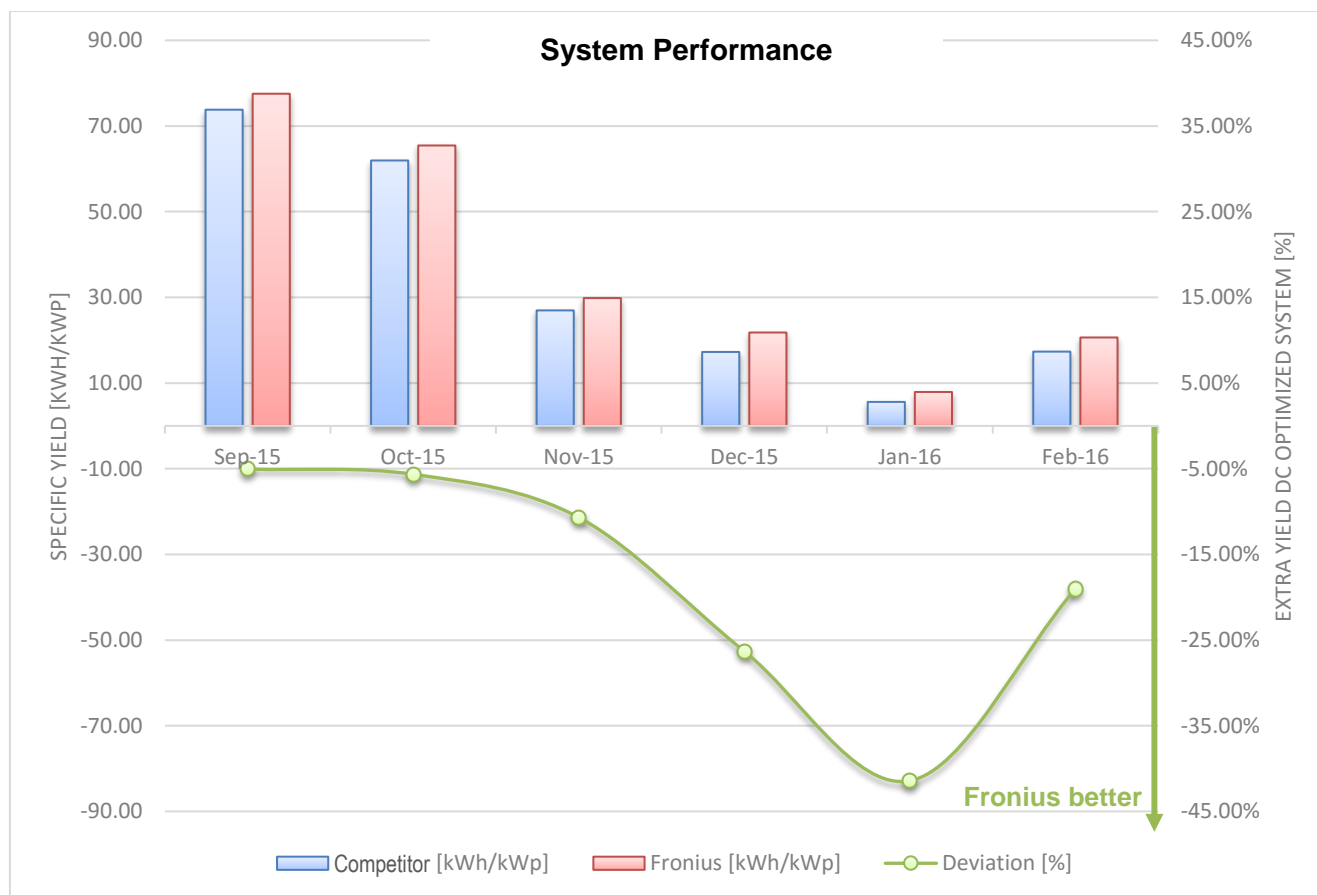


Figure 4: Shaded system comparison in specific yield

The positive effect of optimization in single string systems (unshaded or even slightly shaded) is very poor. It is shown that the Fronius inverter with DPM performs significantly better during the observation period.

### “System B” – unshaded system

#### Yield comparison

Since the two systems have slightly different sizes (SE 17k with 17.68 kWp two strings and Fronius Symo 17.5-3-M with 17.16 kWp three strings) it is necessary to take the specific yield (kWh/kWp) to compare on eye-level. Therefore the achieved energy yield per month has been normalized by dividing the kWp power of the system (17.68 kWp for the DC optimized system, 17.16 kWp for the Fronius).

$$E_{specific} \left[ \frac{kWh}{kWp} \right] = \frac{E_{Total} [kWh]}{P_{DCpeak} [kWp]}$$

Daily yield of the comparison period shows that the Fronius inverter achieves 55Wh more energy per day on average and a total of extra yield of 1.7%.

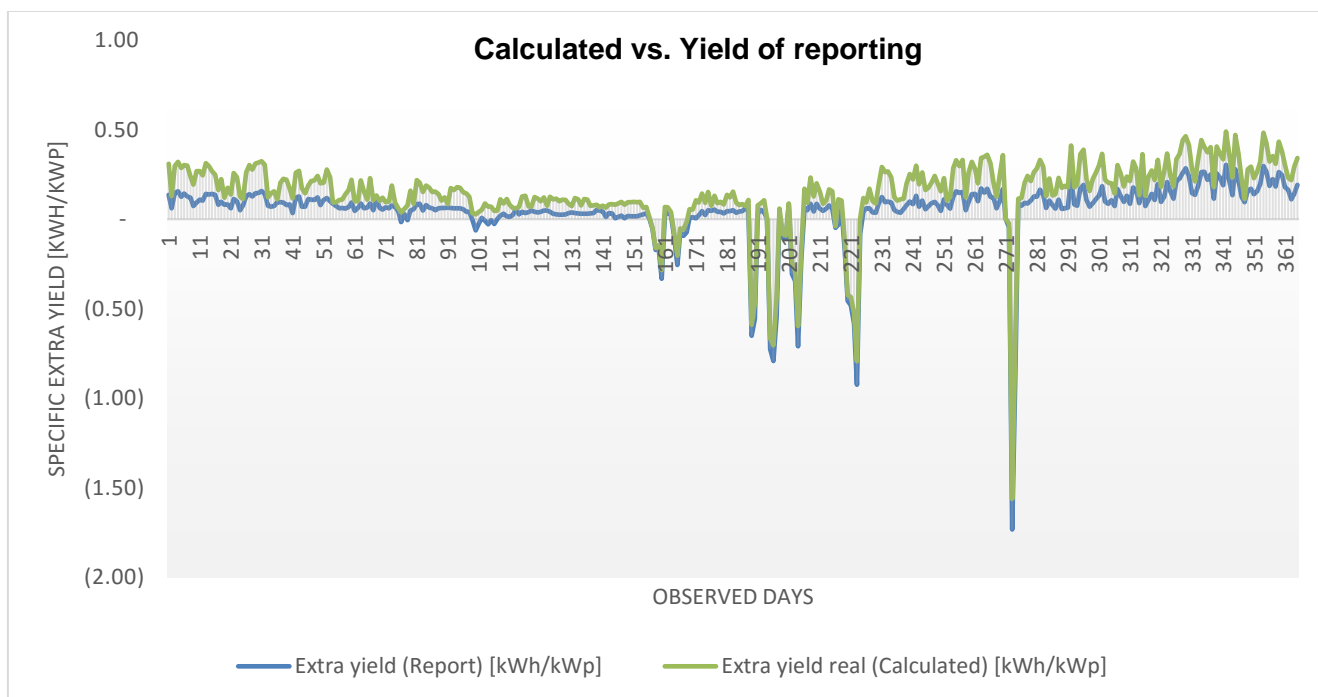


Figure 5: Day-to-day comparison of Fronius and competitor ("Report") and ("Calculated") values

Taking the daily power values into account (5 min log-interval) the energy of the DC optimized system is constantly ~3% lower than the corresponding reported ones. This means the actual average extra yield of the Fronius system is 151Wh per day or a total extra yield of 4.7% during observation period.

Since it cannot be clearly identified which values the competitor's monitoring is offering are the correct ones, we compare the higher energy ("Report") values to make sure not to embellish the comparison in the advantage of Fronius.

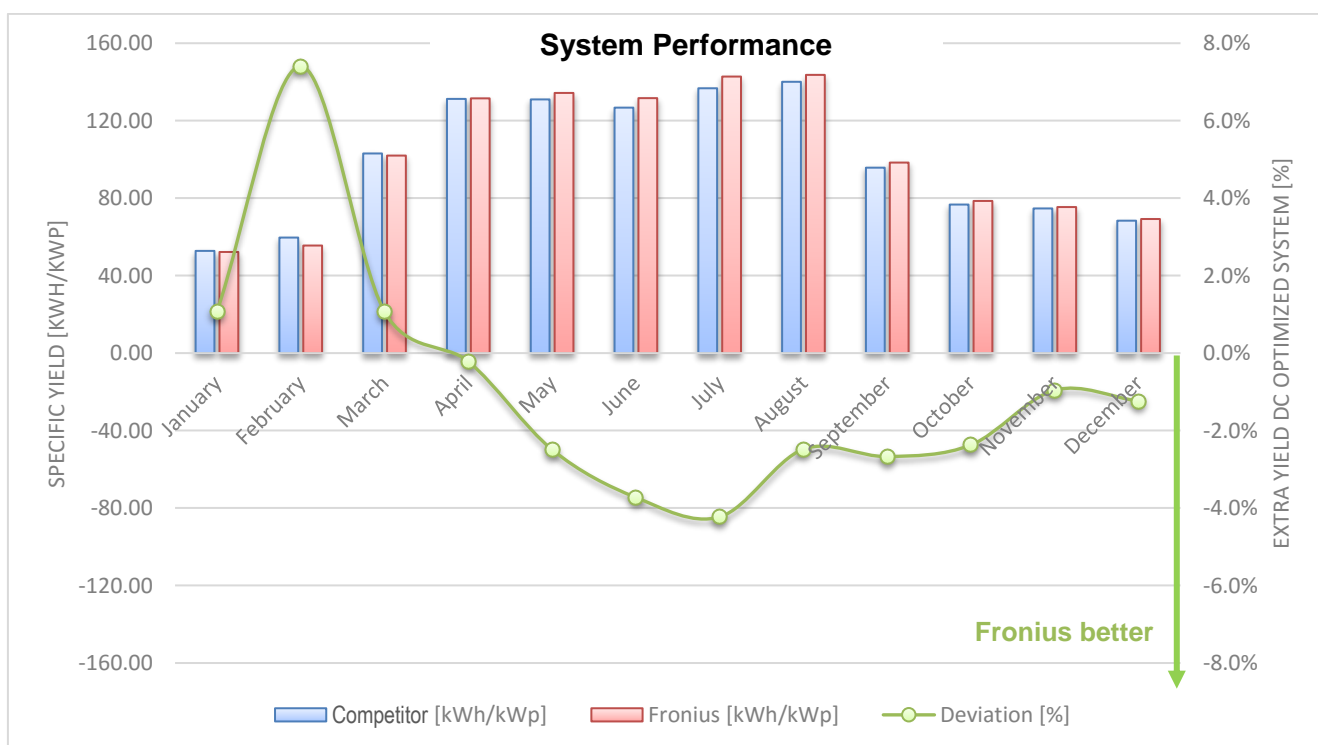


Figure 6: Comparison of specific yield in kWh/kWp and %



The graph in *Figure 6* shows that during winter time the DC optimized system produces more yield on a few days, but this advantage of the competitor occurs during a period of poor irradiation and low yield. This means this is not relevant for the rest of the observation period where Fronius is clearly ahead.

This analysis shows that there are a few days a year where the where the DC optimized system was performing better than the conventional system with Fronius inverters as explained. But the annual view of the yield does not imply any advantage of the DC optimized system in terms of the extra yield.

## SUMMARY

This paper shows that there is a benefit of DC optimized systems under certain circumstances. This benefit typically can be found in times of poor irradiation when there is evidence of snow-cover in the investigated data.

Comparing a Fronius SnapINverter system with a DC optimized system in unshaded conditions the Fronius system is able to achieve a significant extra yield over the full period in particular during times of high irradiation. This is regardless whether retrofit DC optimizers (single module DC optimizers) or module integrated DC optimizers are being used.

Moreover, in single-string systems under homogeneous shading the findings in this paper show that there is absolutely no advantage of optimizers because of the lower overall efficiency of the DC optimized system. This is the result of the outstanding performance of the Fronius Dynamic Peak Manager (DPM) due to its flexible MPPT algorithm. This has also been proven in *Figure 4*.

It is important to point out that the results introduced in this paper are not based on Fronius internal test systems but on real customer systems that have been built to compare technologies in terms of extra yield.

From a financial point of view the premium of a DC optimized system does not justify the extra investment at all.

## REFERENCES

[1] The SuperFlex Design of the Fronius Symo Inverter Series  
([SE TEA SuperFlex Design Fronius Symo EN.pdf](#))

[2] Performance of recent inverter systems under partial shading conditions – Results from side-by-side comparison in a field test (TNC Consulting: Ralph Lingel, Thomas Nordmann, Thomas Vontobel)

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