THE SUPERFLEX DESIGN OF THE FRONIUS SYMO INVERTER SERIES

1. Introduction

The PV applications where the use of more than one Maximum Power Point Tracker (MPPT) makes sense are manifold and diverse. This results in quite different requirements to the characteristics of the MPPT of an inverter with multiple MPPT. Basically the requirements can be summarized as follows:

/ Symmetric generator with different orientations (Inclination angle, Orientation)
/ Asymmetric generator with different orientations (Inclination angle, Orientation)
/ Partial shading on the generator
/ Perfect flexibility in planning (Possibility to connect each reasonable number of modules, possibility to connect all strings in parallel,…)

This paper investigates the effect of those applications on the technical requirements of inverters and how the Fronius Symo inverter series complies with them.

2. Technical requirements

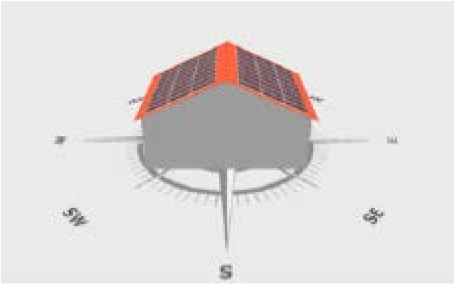
2.1. Symmetric generator with different orientation

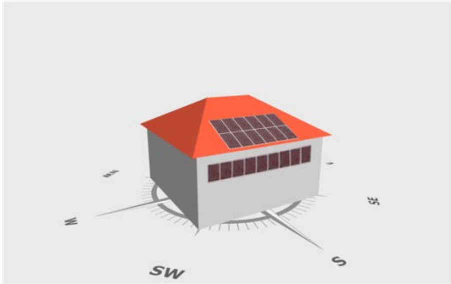
When a PV generator has more than one tilt angle and/ or orientation it is recommended to connect those different generators to independent MPP trackers. Several investigations [1] [2] have shown that, under certain circumstances, even such generators can be connected to a single MPP tracker. However, the design flexibility increases when using a second MPPT. East/ west generators or similar are often designed in a way that the power of both parts is roughly equal. The resulting requirement for the inverter is that both MPPT should be equal concerning their current- and voltage characteristic. That means both MPPT should be able to handle about 50-60 % of the AC nominal power ($P_{ac,nom}$) of the inverter.

Furthermore it is helpful if the maximum DC voltage of the inverter is as high as possible to be able to build systems with as little strings (optimum would be one on each MPPT) as possible.

Applications:

- / Generator with different orientations (e.g. east/west)
- / Generator with different tilt angle (e.g. roof/facade)





Requirements:

	Requirement on MPPT 1	Requirement on MPPT 2
P_{dc} in % of $P_{ac,nom}$	50-60 %	50 %
$U_{dc,max}$	As high as possible (e.g 1000 V)	As high as possible (e.g 1000 V)

Table 1: Requirements on both MPPT to get perfect design flexibility for generators with different orientations.

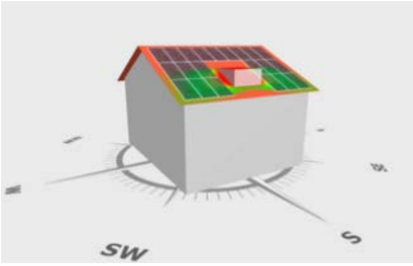
2.2. Generator with partial shading, asymmetric generator with different orientation

To completely avoid small shadows on PV systems is often almost impossible, especially in PV systems on buildings. Therefore inverters with multiple MPPT are quite common in such systems. If a PV system can be built with just one string (typically in systems up to 5 kWp/ 1000 V or 3.5kWp/ 600 V) there is no need to separate the shaded modules from the unshaded ones as it has been demonstrated in [3]. But as soon as the PV system consists of more than one string it is recommended to connect the shaded and the unshaded parts of the system to two independent MPPT. In most cases only a small portion of modules is affected by shading (e.g. by a chimney, tree,…). That means one of the two MPPT should be able to handle almost the whole PV power, whereas the second MPPT only has to deal with the power of a few shaded modules.
Further relevant is the minimum DC voltage ($U_{dc,min}$) of the inverter. If $U_{dc,min}$ is low, it is possible to design the shaded string with just a few affected modules. In addition the voltage of a shaded string might drop below the minimum MPP voltage ($U_{mpp,min}$) as given on the datasheet, which makes it important that the inverter is still able to operate below that voltage.

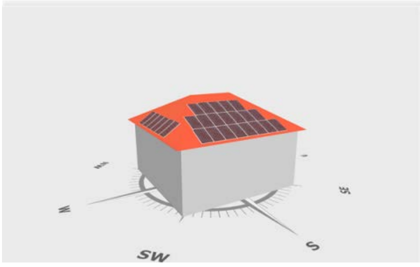
Similar requirements establish when PV systems with different orientations are built where it is not possible or wanted to divide them into two similar sized parts. This might happen when the different sized roof areas are available or when PV systems are mounted on different parts of a building. In such a case it is also necessary to connect almost the whole PV power to one MPPT whereas the second MPPT is only connected to a small portion of the system (similar to a shaded situation).

Applications:

/ Generator with partial shading



/ Generator with small secondary system



Requirements:

	Requirement on MPPT 1	Requirement on MPPT 2
P_{dc} in % of $P_{ac,nom}$	80-90 %	10-20 %
U_{dc}	$U_{dc,max}$: as high as possible (e.g. 1000 V)	$U_{dc,min}$: as low as possible (e.g. 150 V)

Table 2: Requirements on both MPPT to get perfect design flexibility in partially shaded or asymmetric systems.

2.3. Perfect planning flexibility

The use of an inverter with multiple MPPT might be reasonable even if the PV generator is not shaded, because with multiple MPPT available almost every number of modules can be connected to the inverter, and one can make optimal use of the space on the roof. But this is only possible if the inverter is able to connect a small number of remaining modules on the second MPPT. To allow for such a connection the same requirement as for shaded systems becomes true, that one of the MPPT has to be able to handle almost the complete PV power.

Especially in larger systems it can also be reasonable to use DC combiner boxes where all strings are connected and just one DC main cable runs to the inverter. In this case the independent tracking function is not used. But such a design is only possible if both MPPT can operate in parallel, or in other words if one can turn the inverter with multiple MPPT into a single-tracker inverter.

	Requirement on MPPT 1	Requirement on MPPT 2
P_{dc} in % of $P_{ac,nom}$	100 % or parallel operation with MPPT2	10-20 %
U_{dc}	$U_{dc,max}$: as high as possible (e.g. 1000 V)	$U_{dc,min}$: as low as possible (e.g. 150 V)

Table 3: Requirements on both MPPT to get perfect planning and design flexibility.

2.4. Summary

The three different applications result in the following requirements for an ideal inverter with multiple MPPT.

	Requirement on MPPT 1	Requirement on MPPT 2
P_{dc} in % of $P_{ac,nom}$	100 % or parallel operation with MPPT2	50 %
$U_{dc,min}$	No requirement	As low as possible (e.g. 150 V)
$U_{dc,max}$	As high as possible (e.g. 1000 V)	As high as possible (e.g. 1000 V)

Table 4: Requirements for both MPPT for ideal design flexibilty.

3. The SuperFlex Design of the Fronius Symo in comparison

The Fronius Symo inverter series is equipped with two MPPT in the power range from 3-20 kW. The DC voltage window and the current capability of both MPPT are chosen in a way that both symmetric (typical east/west systems) and asymmetric (shaded systems, small secondary system) systems can be realized very easily. The minimum input voltage is in the range from 150-200 V and the maximum input voltage is 1000 V. In total all described requirements above are fulfilled very well. The following diagram shows a comparison of the Fronius Symo series with other inverters with multiple MPPT available on the market. The bars in the diagram show what systems can be realized with the corresponding inverter. The diagram shows a variation from highly asymmetric systems (power ratio of 10/90 for both generator parts on the left hand side) up to symmetric systems (power ratio of 50/ 50 for both generator parts on the right hand side). E.g. the Fronius Symo 5.0 can handle power ratios from 50/ 50 down to 30/ 70. In general it can be seen that in the area up to 10 kW most inverters can quite well deal with symmetric systems whereas asymmetric connections become difficult or impossible. Above 10 kW rather asymmetric designs are possible. Due to the SuperFlex Design the Fronius Symo series in contrast is able to deal with symmetric and asymmetric systems over the whole power range. Note: All calculations are based on systems with typical 6”-cell modules of around 240 W.

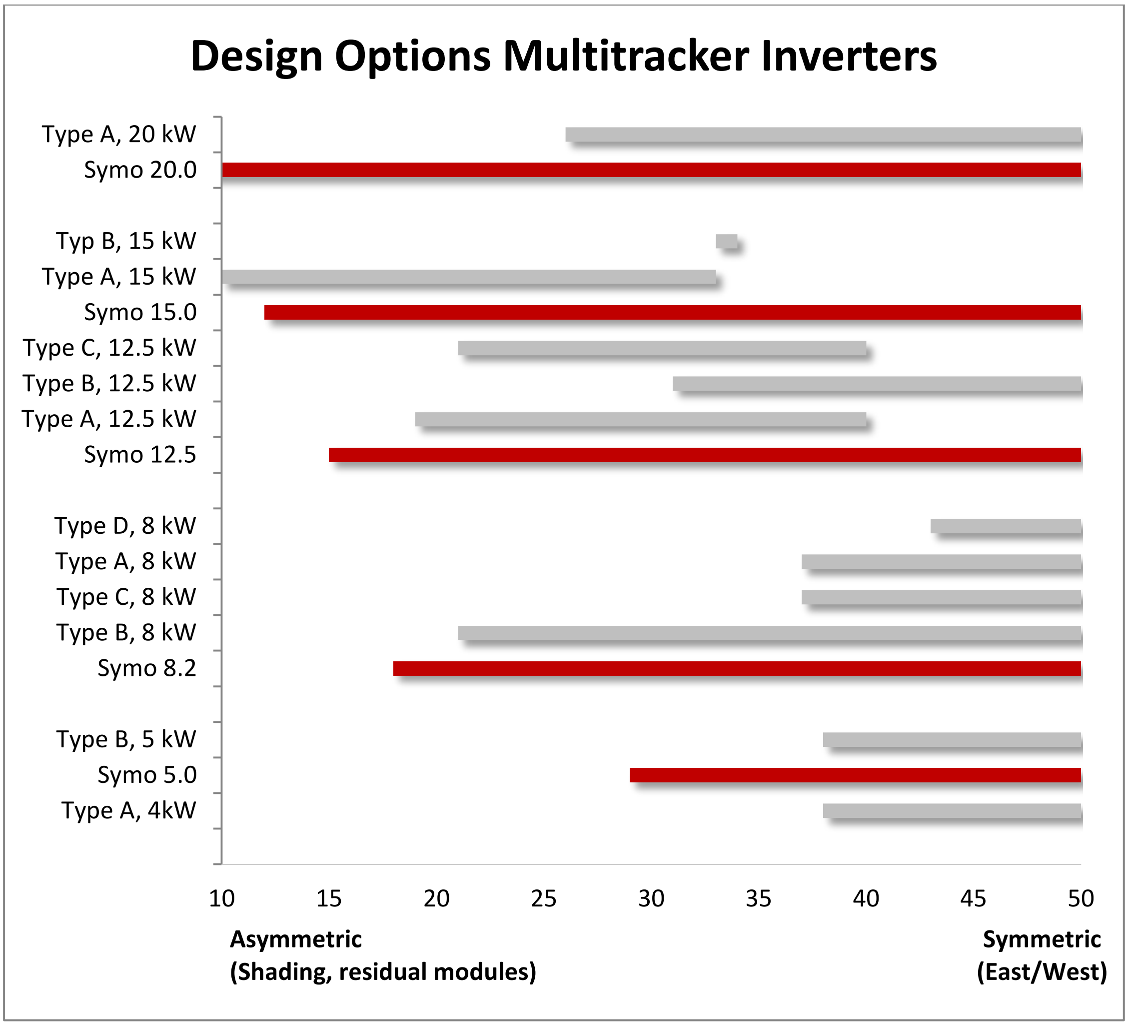


Diagram 1: Dimensioning comparison of Fronius Symo with other inverters

4. Behaviour in shadowing conditions

The technical characteristics of both MPPT are quite relevant to provide ideal dimensioning options in PV systems with partial shading as shown in chapter 2. Furthermore the question arises if the inverter or the corresponding MPPT is able to find the maximum power point of the generator in a shaded system. As shown in [3] the P(U) curve (Power vs. Voltage) of a shaded system can easily establish a local maximum in addition to a global maximum as given in diagram 3. Depending on the characteristic of those maxima and the MPP tracking algorithm of the inverter, the inverter might get stuck in the local maximum. In this case the system would not output its maximum yield. To avoid such a situation a new tracking algorithm, the so called Dynamic Peak Manager, is implemented in the Fronius Symo that enables the inverter to reliably find the global maximum. Hence, the Fronius Symo not just enables easy dimensioning of the system, but also minimizes shading losses during operation.

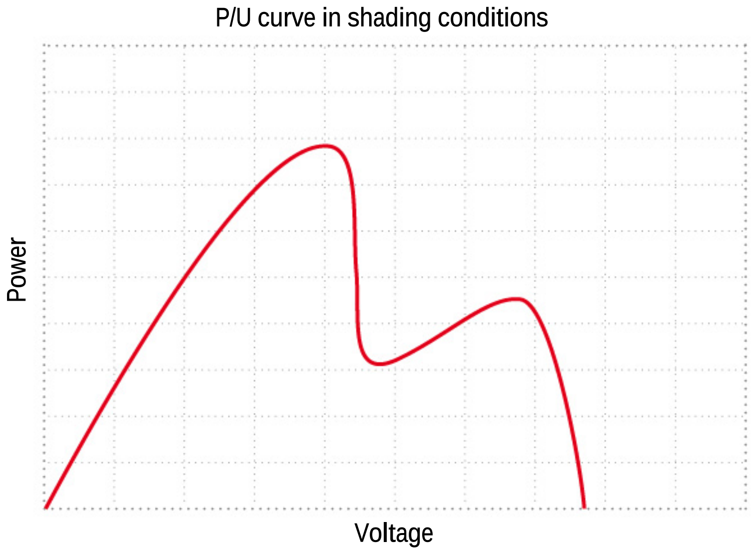


Diagram 2: P/U curve of a shaded PV generator with global and local maximum.

5. Summary

Various applications in PV system design put partly contradicting demands on the MPP tracker characteristics of inverters. Typical east/ west oriented systems require inverters with symmetric power distribution between the two MPPT and high input voltages. On the other hand is an asymmetric power distribution beneficial for shaded systems or generators with a small residual system.
The SuperFlex Design of the Fronius Symo combines both requirements in an ideal way and is therefore universally applicable. Besides that the Dynamic Peak Manager, the optimized MPP tracking algorithm, provides maximum yield in shaded conditions.

6. Annex: Dimensioning Examples

The following tables provide a quick overview concerning the design flexibility of certain models of the Fronius Symo series. All examples are based on systems with typical 6"-cell modules of around 240 W.

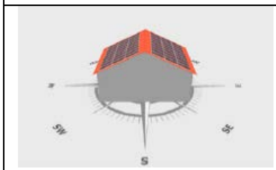
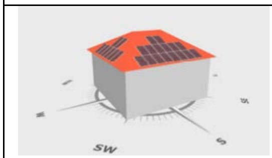
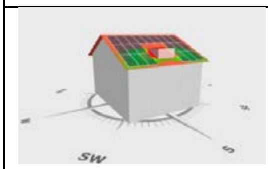
Application: Connection of 46 modules to a Fronius Symo 10.0	Required module number on…		Degree of symmetry	Connection options		
	MPPT1	MPPT2			MPPT 1	MPPT 2
	23	23	high	✓	1x23	1x23
	24	22	high	✓	2x12	1x22
	25	21	high	✗	---	---
	26	20	medium	✓	2x13	1x20
	27	19	medium	✓	3x9	1x19
	28	18	medium	✓	2x14	1x18
	29	17	medium	✗	---	---
	30	16	medium	✓	2x15	1x16
	31	15	low	✗	---	---
	32	14	low	✓	2x16	1x14
	33	13	low	✓	3x11	1x13
	34	12	low	✓	2x17	1x12
	35	11	low	✗	---	---
	36	10	low	✓	2x18	1x10

Table 5: This design example shows 10 different connection options (with different degrees of symmetry) when connecting 46 PV modules to a Symo 10.0.

Application: Connection of 46 modules to a Fronius Symo 10.0	Required module number on…		Degree of symmetry	Connection options		
	MPPT1	MPPT2			MPPT 1	MPPT 2
	12	11	high	✓	1x12	1x11
	13	10	medium	✓	1x13	1x10
	14	9	medium	✓	1x14	1x9
	15	8	low	✓	1x15	1x8
	16	7	low	✓	1x16	1x7

Table 6: This design example shows 5 different connection options (with different degrees of symmetry) when connecting 23 PV modules to a Fronius Symo 5.0.

7. References

[1]… Efficient East-West orientated PV Systems with one MPP-Tracker, 25th European Photovoltaic Solar Energy Conference, Spain, 2010

[2]… Auslegung von PV-Anlagen im Polystring-Betrieb –Eigenverbrauchsoptimierung vs. Mismatch-Verlust, 27. Symposium Photovoltaische Solarenergie, Bad Staffelstein, 2012

[3]…Monostring vs. Polystring, Technical Analysis Fronius