Shade Management

Efficient Operation of Partially Shaded PV Systems with OptiTrac Global Peak

Content

It is not always possible to prevent dormers, chimneys, or trees from casting their shadows on PV systems.

However, in order not to jeopardize the economic viability of a PV system, output losses resulting from shade must be minimized already in the planning phase.

Influential factors such as the arrangement of the PV modules, their circuitry and in particular the choice of an appropriate inverter play an important role.

By observing some important planning rules, these factors can be adapted to the respective PV system in such a way that their energy supply can be used almost completely.

1 Effects of Partial Shade on the PV System

Each PV array has an individual operating point where it can provide the highest electrical power, the Maximum Power Point (MPP). The amount of power depends mainly on the irradiation. If individual PV modules of a string within the PV array are shaded, its electrical properties change significantly: the PV array now has several operating points of different qualities.

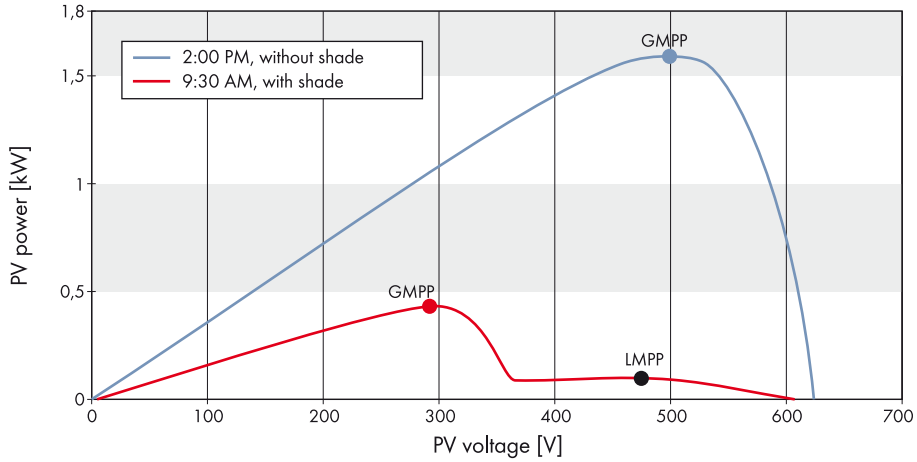

Fig. 1: Power-voltage diagram of the represented PV array at two different times of day (with and without partial shade). The curves show that there are two MPPs with different qualities when there is shade, with the power at the local MPP being significantly lower than that at the global MPP.

2 Shade: A Special Task for the Inverter

Each PV inverter has a so called MPP tracker. This ensures that the PV array is continuously operated at its optimum operating point. Controlled in this way, the PV array can use the available power at a certain level of solar irradiation in the best way possible. For SMA inverters, OptiTrac operation control takes on this task, thus ensuring maximum energy yield.

But if, as described above, the shading of individual PV modules of a PV array creates two different operating points, the connected inverter must now decide on which of these two operating points - the local MPP (LMPP) or the global MPP (GMPP) - it should operate the PV array.

However, since conventional MPP trackers only monitor the vicinity of the current operating point, an alternative operating point may not be noticed in order to avoid unnecessary loss during the searching procedure. The current output of the PV system can thus be significantly smaller than estimated because of the shade.

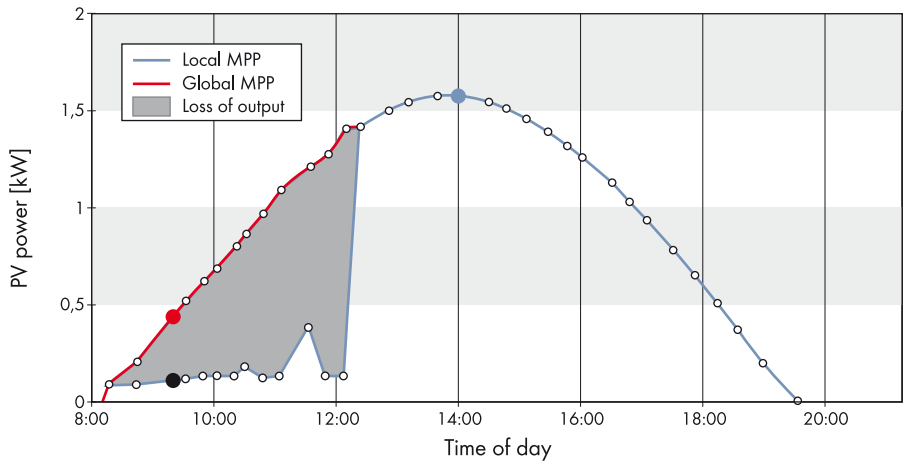

Fig. 2: Course of the global and local MPP power of a partial array of a PV system with morning shade. The gray area shows the loss of output that would be caused by setting the local MPP instead of the global MPP.

OptiTrac Global Peak behaves quite differently: in order to always find the optimum operating point even in partially shaded PV systems, an additional function was added to the standard MPP tracking of SMA inverters. OptiTrac Global Peak can temporarily operate the PV array at a great distance from the known operating point. With the help of this function, the inverter can always find the operating point with the currently highest performance and in this way can almost completely use the energy supply of the PV modules under all conditions [1].

With this procedure, losses during the searching procedure are unavoidable. However, OptiTrac Global Peak is a search procedure specialized in keeping losses in times without shade at a maximum of 0.2% when searching for a possible second power maximum. To keep these search losses even lower, it may be useful to adapt and reduce the frequency of searches (cycle time) individually for PV systems with slowly appearing shadows.

3 Designing Partially Shaded PV Systems

In order not to jeopardize the economic viability of partially shaded PV systems, the loss of output due to shade must be minimized already in the planning phase.

To assist the system system planner, the most important planning rules are presented below.

3.1 Selecting the Roof Area

The minimization of energy losses in partially shaded module strings is always based on enabling the inverter to electrically bypass shaded PV cells and thus to optimally use the unshaded PV modules of the same series-connected string. The power of the shaded PV cells, which is diminished anyway, cannot be used at this time. Therefore, when selecting the roof area for a PV system, you should make sure that no permanent shadows fall on the PV array, and especially in times of high irradiation (noon, summer months) no shadows should fall on it at all, if possible. To estimate the properties of the shadows, such as their size and how they change over the course of a year, special simulation programs can be used.

3.2 Selecting the System Connection

The connection of the PV array significantly influences the obtainable energy yield.
SMA Solar Technology AG has therefore prepared and published the rules of "Shadow Management" [2]. The analysis of the course of shadows is always carried out at the beginning of a system design. The proportion of the shaded PV modules in relation to the total array and the course of shadows over time are important characteristics of a PV system with partial shading. The following recommended actions are important when dealing with partially shaded PV systems:

- When a single PV module or a very low portion of the PV modules (e.g. < 10% of the total number) is shaded, the shadow can be distributed evenly on the strings. Since the MPP voltage is always near the nominal MPP voltage in these cases, a special operation control (OptiTrac Global Peak) is not necessary.
- If shading is severe, it makes sense to operate the shaded and unshaded PV modules separately. Observe the following:
  - Group together generator array with similar irradiation.
  - No parallel connection of strings with different irradiation; provide a separate MPP tracker for each string. Many small inverters or ones with multistring technology can be used for this.
  - OptiTrac Global Peak is necessary to maximize the energy yield.

But even with the slight shading described above, the concentration of the shaded PV modules on its own MPP tracker represents an alternative to evenly distributing the shadow over all strings. Even this system design requires OptiTrac Global Peak to minimize yield losses.

3.3 Selecting the Inverters

As described in "Shadow Management" [2], the choice of the inverter also influences yield losses due to shade. Three points are to be observed when selecting the inverter:

- Inverters with a broad input voltage range can still adjust the optimal operating point despite shade and the resulting decline in MPP voltage.
- Using an inverter with a single-string control a partially shaded PV array can operate optimally and avoid most losses.
- To keep yield losses due to shade to a minimum, it is necessary to use an inverter for partially shaded strings whose MPP tracking recognizes the presence of several operating points (e.g. OptiTrac Global Peak).

4 OptiTrac Global Peak

SMA OptiTrac Global Peak is an advancement of SMA OptiTrac and allows the operating point of the inverter to follow the MPP precisely at all times. In addition, with the aid of SMA OptiTrac Global Peak, the inverter can detect the presence of several maximum power points in the available operating range, such as may occur particularly with partially shaded PV strings. The function is deactivated by default. You will find further information on activation and settings of OptiTrac Global Peak in the installation manual of the particular inverter.

5 Sources

[1] J. Iken: "Leistungsgipfel mit Geheimnissen" (Performance peak with secrets); Sonne Wind & Wärme, 17/2009, p. 160 (only available in german)

[2] G. Bettenwort, J. Laschinski: "Schattenmanagement – Der richtige Umgang mit teilverschatteten PV-Generatoren" (Shadow management – The correct handling of partially shaded PV arrays); 23. Symposium Photovoltaische Solarenergie, 2008, Bad Staffelstein, Germany (only available in German)