Technical Note – Optimizing Thin-Film Module PV Systems

Introduction

Crystalline modules and thin-film modules differ in structure: crystalline modules typically consist of individual square cells (Figure 1), while thin-film modules are typically made up of cell strips (Figure 2), which create their characteristic pinstripe look. This results in different module voltages and currents, as well as in different behavior in shading conditions.

The purpose of this document is to describe the behavior of thin-film modules in various conditions, and the benefit of using power optimizers in each case.

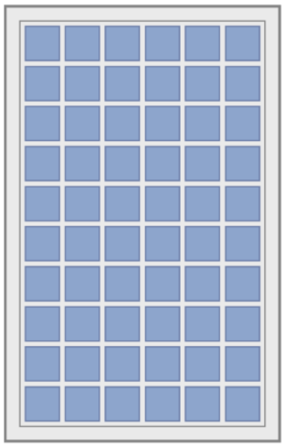


Figure 1: Typical structure of a crystalline module

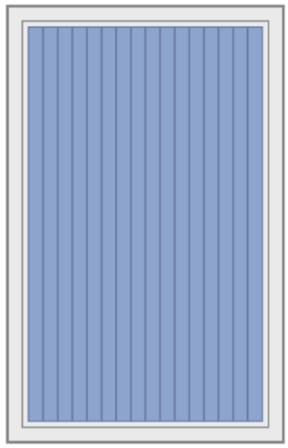


Figure 2: Typical structure of a thin-film module

Shading Considerations

Many thin-film modules are considered more immune to shading effects, as bypass diodes are often unnecessary due to the large surface area of the cells and the low cell current compared to that of crystalline modules. Accordingly, only cells affected by shading do not contribute to energy generation. In contrast, in crystalline modules the entire sub-string protected by a bypass diode does not contribute when part of it is shaded (Figure 3).

In addition to this, the pinstripe cell layout generally reduces the effect of shading. In cases of even shading, e.g. inter-row shading (Figure 6)), the shading across the module is uniform, minimizing mismatch losses. Depending on the module layout, either the string current (Figure 4) or the module voltage (Figure 5) decreases.

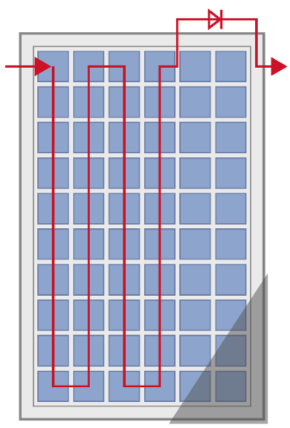


Figure 3: Bypass diode impact

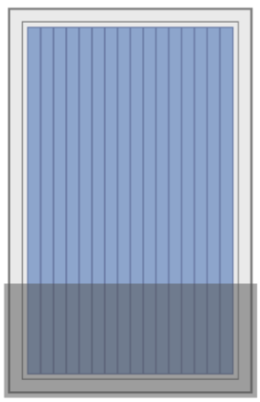


Figure 4: Horizontal shading

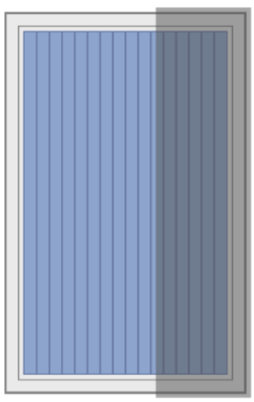


Figure 5: Vertical shading

The impact of horizontal shading on string mismatch is limited if all modules are equally shaded. However, in the case of inter-row shading, the first row of modules is unshaded while the others are shaded. In other words, mismatch losses will occur in strings which extend through the first and second (or more) rows (Figure 6). Using power optimizers avoids these mismatch losses.

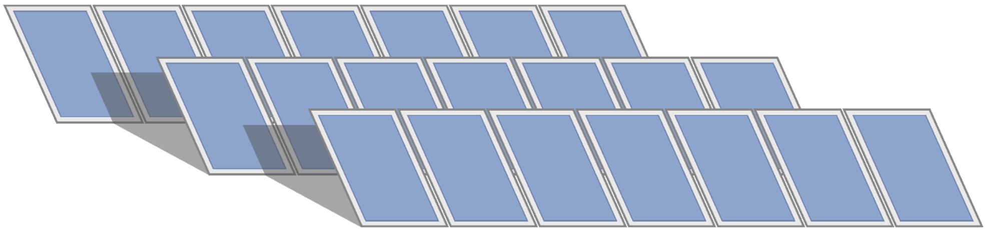


Figure 6: Inter-row shading

If vertical shading fully covering cell strips occurs, there are no mismatch losses as the string current remains constant. This is the case even if the string contains unshaded modules and shaded modules. However, in that case the lack of voltage in the shaded cell strips can cause voltage mismatch between parallel strings leading to losses. In some cases the voltage may fall below the minimum MPP voltage. That means that if the MPP voltage range of the inverter is 570-800V for example, and the shade-free MPP voltage is 700V, the voltage drops below the minimum MPP voltage when only 20% of the cells are shaded (80% x 700V = 560V). If this occurs, losses result as the string no longer runs at the optimal operating point. In the worst case, the inverter could be deactivated. In such situations, power optimizers with a fixed DC string voltage keep the voltage at the inverter's optimal operating point and avoid the associated losses. The individual modules in the string continue to run at the optimal operating point.

Mismatch losses also occur in thin-film systems with uneven shading (e.g. commercial roof-mounted systems, as in Figure 7). While these losses are lower than those in systems with crystalline modules, as the bypass diode does not bypass unshaded cells, they remain significant. Depending on the extent of this uneven shading, and any additional even shading due to inter-row shading, the mismatch losses can be much greater than anticipated for "shade-resistant" thin-film systems.

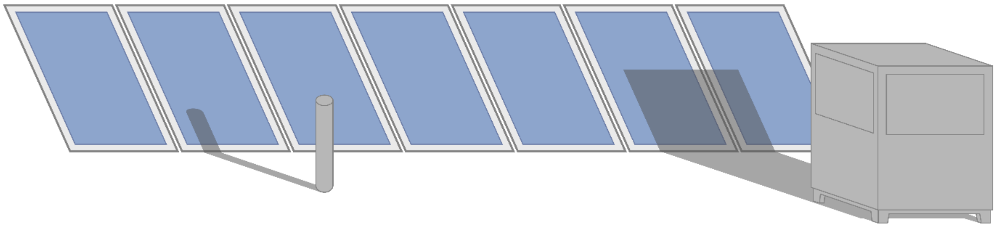


Figure 7: Uneven shading

In other words, system designers must consider mismatch losses for all shading scenarios. While the impact on thin-film systems is lower than the impact on systems with crystalline modules, it cannot be ignored. Using power optimizers prevents the mismatch losses and provides designers with greater flexibility.

Module Tolerances

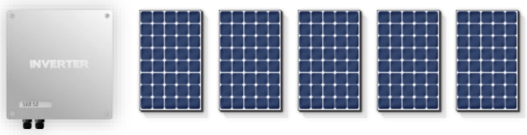
Thin-film modules often have higher current and voltage tolerances. That can lead to greater mismatch losses within a string. The lower fill factor generally counteracts this disadvantage, which reduces the effect of deviations from the MPP point. Mismatch losses generally depend on how much the individual module actually varies within the permitted bandwidth. The higher the variation of the individual module, the greater the energy benefit when using power optimizers.

The monitoring functions offered by power optimizers reveal the actual deviations of individual modules. These differences are typically not detected in traditional systems.

String Connection

Due to the high number of individual cells, lower cell and module currents and higher module voltages are typical of thin-film modules. That means that relatively few modules can be connected in series. Some thin-film modules have higher voltages during their initial operation, further reducing the possible string length. Power optimizers can reduce the output voltage and increase the output current, allowing far more modules to be connected in series. With single phase SolarEdge inverters, up to 5,250Wp can be connected in series, and up to 11,250Wp with three-phase SolarEdge inverters. This reduces connection and wiring complexity and subsequently reduces installation costs significantly (Figure 8).

Traditional single phase string inverter ➡ 4-7 x 170W thin-film modules



SolarEdge single phase inverter ➡ up to **30** x 170 W thin-film modules

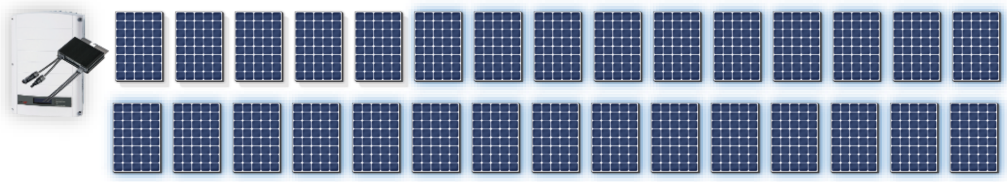


Figure 8: String lengths comparison example: string inverter vs. SolarEdge inverter

The typically high module voltages, which can exceed 100V, mean that the inverter design is quite restricted. As a result, there are generally only one or two options for string length (i.e. the number of modules connected in series), for example 5 or 6 170W modules per string. That means the system cannot always accommodate the precise number of modules required on the roof. For example, if designing a 4kW system using the modules above (i.e. modules that can be connected in strings of 5 or 6 modules only) the system will either not utilize the full roof space – if connecting 24 or 25 modules (5x5 modules or 4x6 modules) - or will exceed the given space or permitted system size – if connecting 30 modules (6x5 modules or 5x6 modules).

Power optimizers allow you to use the exact number of required modules. On one hand, that allows the inverter to be dimensioned for maximum economy, while on the other hand the flexible number of modules means the roof surface can be covered optimally.

Module Power Loss

Thin-film modules (as well as crystalline modules) may exhibit fault mechanisms that cause the modules to lose power over time. While crystalline modules can suffer from PID (Potential Induced Degradation), thin-film modules have irreversible mechanisms such as TCO corrosion. That means that module damage and the associated power losses cannot be rectified. As a result, it is important to detect the onset of damage as early as possible. As the causes of the fault mechanisms are often related to the respective module's voltage to earth or to the environment, the power drop generally starts at one end of the string (Figure 9).

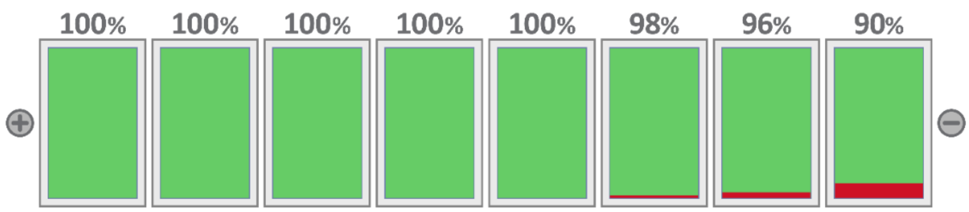


Figure 9: Power loss within a string

In the example shown, the string performance is 98% of the potential performance. Even when using an external sensor, the deviation is within the measurement tolerances, and therefore can easily go undetected. Due to the typically low cell and module currents, thin-film modules must be connected in parallel, i.e. information on individual string currents and module currents is lost. The problem cannot be detected until the faulty module has such an adverse effect on the string current that mismatch losses cause the entire string to perform poorly. In other words, problems with individual modules are not noticed until it is too late.

Power optimizers, which also provide module-level monitoring, detect this type of problem at an early stage even when a single module is affected. The earlier detection reduces risks to the operator and damage to the system.

BIPV

Thin-film modules are particularly popular in BIPV – Building Integrated PV. They are often preferred due to their uniform appearance, and additionally these installations are far more frequently affected by shading. In particular, vertical surfaces are generally affected by shading to a greater extent, e.g. by neighboring buildings and canopies.

In situations like these, power optimizers reduce the mismatch losses from shading. Furthermore, module performance monitoring indicates whether losses are due to shading or to faults in the system. The additional safety functions like module shutdown are particularly important for building-integrated systems.

Summary

Although many thin-film modules have lower shading losses by design, system designers must assess the maximum acceptable level of shading. In particular the overall costs of the system, including higher wiring costs, and voltages outside the MPP range are often not taken into account. The use of power optimizers overcomes these effects and reduces costs, and adds value to customers with additional functions like module-level monitoring and shutdown.