Tigo energy

# Design Guide

## Introduction

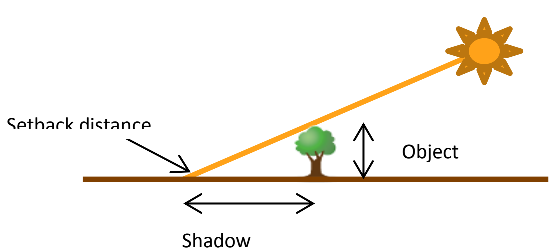
Smart Modules significantly expand the design possibilities for solar installations. Optimized modules can be designed into shade, installed on multiple orientations and arranged in uneven strings. The Smart Modules technology allows each module to operate at its own maximum power point using patented Impedance Matching technology. Designers using Smart Modules no longer have to follow many of the traditional design restrictions. This allows for expanded design parameters, real estate maximization and system design flexibility.

## Designing into Shade

Traditionally shade is avoided when designing a solar array; however, using Smart Modules can mitigate the mismatch caused by shading. Shadows constantly change throughout the day and year, thus restricting how close any module can be placed to an obstruction. As little as one or two shaded modules can have a negative impact on the entire array. By creating panel level MPPT this effect is mitigated and shade becomes tolerable. The following section will provide a general process for determining how much shade can be designed into a system based on how much energy the Smart Modules can recuperate from potential mismatch losses.

### Setback Distance in Standard Arrays

In standard arrays the amount of space between any obstruction and the solar array (setback distance or holdout) is determined based on the sun chart for a particular region. The general rule of thumb is that the setback distance should be three times the object height. Often, this means underutilized roof or ground space. With Tigo, this setback distance is reduced.




The annual energy production of a PV system in San Francisco was modeled with different setback ratios. The percentage of hours per year impacted by shading is shown in Figure 1. With a setback ratio of 1.5, 14% of annual hours are impacted. Increasing the setback ratio reduces the amount of annual affected hours dramatically.

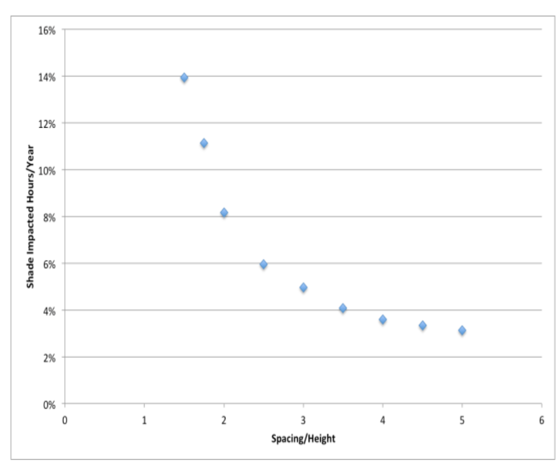



**Figure 1:** The Effect of Shade—Without Tigo Energy

### Setback Distance Reduced with Tigo Energy and Smart Modules

The amount of shade you can design into your system is determined by how much energy a Smart Module can recuperate from mismatch. Let's conservatively say that 50% of the lost energy can be recuperated from a shaded module. Therefore, the percentage of annual impacted hours is reduced, as shown in Figure 2. The Smart Module allows you to produce the same amount of energy with a much smaller set back distance thus enabling you to better utilize your available roof-space.

Referring to Figure 2, we can calculate the effect of Tigo Energy optimizers on the setback distance using the following equation:

.14 (Percentage of annual hours impacted) x .50 (Percentage of energy Tigo can recuperate)

x .75 (percentage of hours Tigo optimizers are mitigating shade in this particular installation)

= 5% Percentage of annual hours impacted

Smart Modules provide the same percentage of affected hours as a standard array with only half of the setback ratio.  . While each system is different, you can assume your setback ratio can be reduced by approximately 50%.

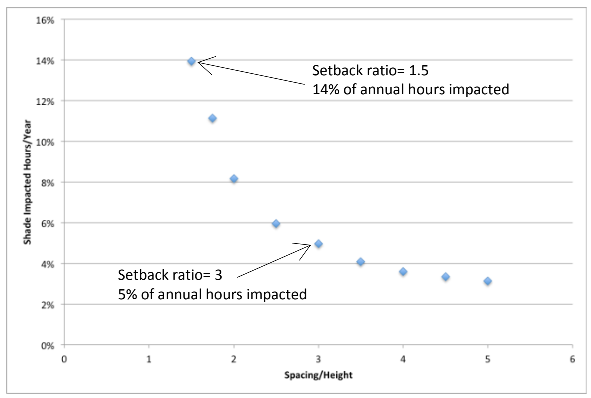



**Figure 2:** The Impact of Tigo Energy optimizers

### Summary of Designing into Shade

1. Tigo can reduce the setback distance of modules from an obstruction by approximately 50%. In many cases this may be more.
2. Tigo Energy optimizers will enable modules that are always shaded throughout the day produce whatever power is available from indirect light.

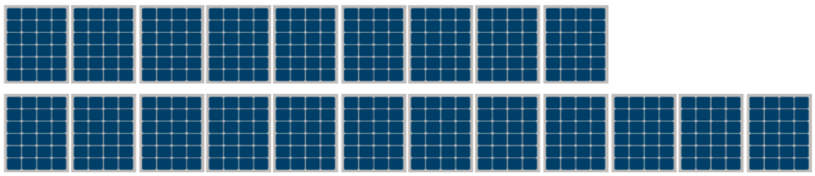
## Designing Uneven Strings

Smart Module technology also corrects for mismatch which results from uneven strings. It enables a variance in string length of up to 25%.

### Here are some important guidelines to follow when designing strings of different lengths

1. Strictly follow the inverter minimum and maximum MPP voltage windows.
2. Be aware that the overall industry guidance to design the stings as long as possible to reduce homerun losses and improve efficiency.

3. Design shade on the longer strings or evenly across strings as much as possible.
4. Have the number of longer strings as low as possible (i.e. prefer 2 shorter strings and 1 long than only 1 shorter string and 2 long strings).



### How to Calculate Maximum Strings Mismatch

To calculate maximum amount of string-to-string mismatch use the following equation.

1-(short string/long string)= % mismatch; must be less than or equal to 25%

Short string voltage must be above the inverter MPP minimum and the longest string must be below the inverter MPP maximum voltage. Remember to adjust the voltage of the shorter string for the historical high temp for your area.

## Mix and Match Different PV Modules

Tigo Energy enables system designers to mix different panel types within the same string. For example, if a particular panel needs replacing and the technology is now outdated or the manufacturer is no longer around you can replace with something different. It can eliminate the need of keeping additional inventory for such replacements throughout the life of your system.

Retrofitting a system with Tigo optimizers allows you the same 25% flexibility when choosing replacement modules.

### How to Calculate Different PV Modules Mismatch

Within a string, the only thing that matters is current. Therefore, you can mix and match panels in the same string as long as the current ratio remains bigger than 0.75, which is equivalent to:

1-(lower current module/higher current module)= % mismatch; must be less than or equal to 25%

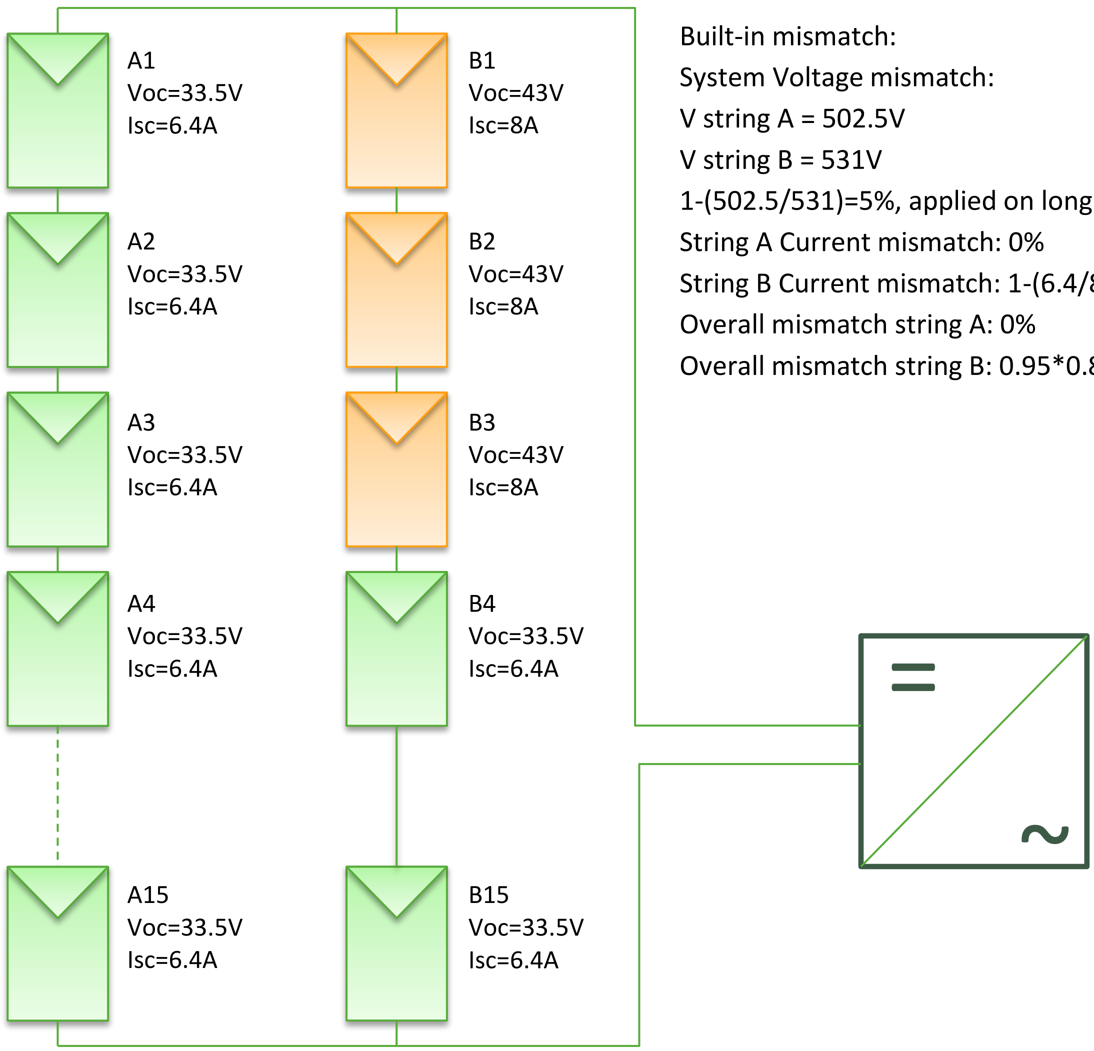
Voltage wise it is a bit more complex, as it effects the string to string mismatch. 2 scenarios:

1. If you have one string, voltage variance has no limit other than maximum voltage allowed per string.

2. If you have more than 1 string, the voltage variance allowed is limited by the ratio between the lowest voltage string to the highest voltage string. For example, see the following drawing of a system with 2 strings, 15 PV modules per string; total array of 30 PV modules. The system is equipped with 2 different panel types: 27 modules with Voc=33.5V and 3 PV modules with Voc=43V. Possible configuration: One string with 15 modules of 33.5V (1st string voltage is 15*33.5V=502.5V), second string with the

remaining panels (2nd string voltage is 43V*3+33.5V*12=531V). The voltage variance is 502.5V / 531V = 0.95 so 5% voltage variation, and therefore for this specific combination it works.

At the end, ensure that overall mismatch doesn't exceed 25%. Going back to the example, the 33.5V modules have Isc=6.4A and the 43V have Isc=8A. The overall mismatch would be current mismatch (6.4A / 8A = 0.8) multiplied by voltage mismatch, so 0.8*0.95 = 0.76: 24% overall system mismatch.




Built-in mismatch:
System Voltage mismatch:
V string A = 502.5V
V string B = 531V
1-(502.5/531)=5%, applied on long string
String A Current mismatch: 0%
String B Current mismatch: 1-(6.4/8)=20%
Overall mismatch string A: 0%
Overall mismatch string B: 0.95*0.8=24%

Notice that this example also demonstrates that the power variation between the different modules has no restrictions. As long as current and voltage variations obey the 25% rule, you can mix and match modules with any power rating or technology available: Mono-crystalline, Multi-crystalline and even Thin-film.