Modeling Maxim Solar Cell Optimizers in PVSYST

Summary

This white paper describes a methodology for using PVSYST® software to estimate the energy production performance of solar panels incorporating Maxim Solar Cell Optimizer technology.

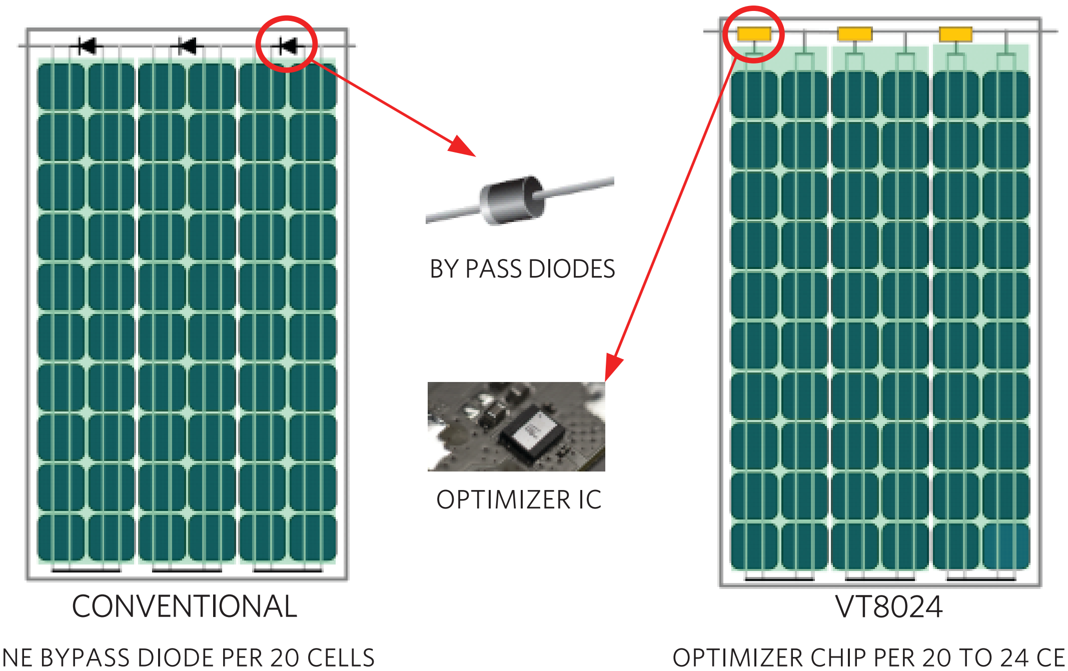
Maxim's Solar Cell Optimizers offer a unique optimization technology, imparting robust shade tolerance to solar panels at a minimally incremental cost. Benefits from the shade tolerance extend from highly challenged residential designs to "near-perfect" utility scale designs.

This document will focus on a methodology for estimating the performance benefits in PV systems employing fixed-tilt arrays. This type of installation is common on large commercial rooftops as well as ground-mount utility scale fields. More specifically, we will explore the methodology for estimating the performance benefit caused from row-to-row shading (mutual shading). We will demonstrate how Maxim's optimized arrays enable higher ground coverage utilization without the losses typically incurred when the spacing between rows is decreased.

PVSYST is a commercial software platform developed and owned by PVSYST SA. This document provides direct examples with settings and screen shots from PVSYST version 6.0. Similar concepts and modeling suggestions might also apply to other revisions. Visit their website at http://www.pvsyst.com for more details.

1. Overview

Maxim Solar Cell Optimizers are breakthrough devices that perform maximum power point tracking (MPPT) on individual cell strings within a PV module. The optimizer sits in lieu of the bypass diodes and provides electrical isolation for each cell string. With this isolation, each cell string can operate at its own maximum power point (MPP) regardless of the power capability of the other cell strings.



Extending electrical isolation to every cell string enables both significant performance benefits and flexibility in a PV site design. Fundamentally, the performance benefits derive from the Optimizer's ability to adjust cell string current and voltage characteristics while keeping the product constant (for constant power). This enables the elimination of all loss mechanisms arising from variation in cell string current output; such as panel or cell level mismatch (typically caused by variations in factory power output, aging variations, temperature gradients, soiling gradients, etc) and row-to-row shading.

PVSYST models the panel mismatch, soiling, and other panel-to-panel variations as constant parameters editable by the site estimator. We will later describe where the various parameters are entered in the software and Maxim's suggestions for modeling performance with the Solar Cell Optimizer-enabled panels.

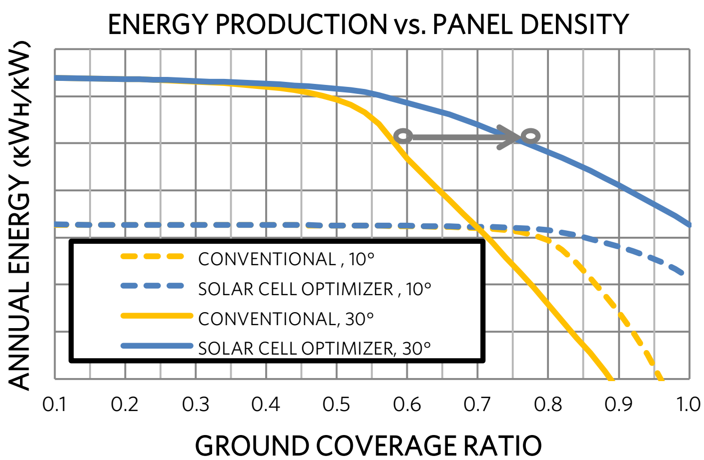
PVSYST models row-to-row shading (sometimes referred to as mutual shading or cross-bank shading) with a simple "electrical region" model of the fixed-tilt array. We will outline appropriate settings for several PVSYST parameters to reflect the cell-string optimization performance benefits.

2. Improving Ground Utilization and Density

PV systems designed with fixed-tilt arrays require careful consideration of the spacing between rows in order to minimize the impact of shading from one row to the next. If rows are placed very far apart then there is little-to-no mutual shading but large land areas or rooftops are needed to meet energy production needs. If rows are placed too close together then energy production is curtailed by significant row-to-row shading during otherwise sunny periods of the day.

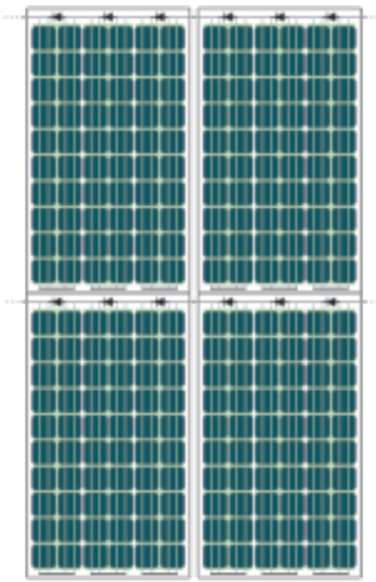
Every PV project has different requirements that will influence the final selection in the row spacing or ground coverage trade-off. The tolerable level of row shade losses will generally be a function of energy requirements, land or rooftop area available, latitude, and module racking equipment.

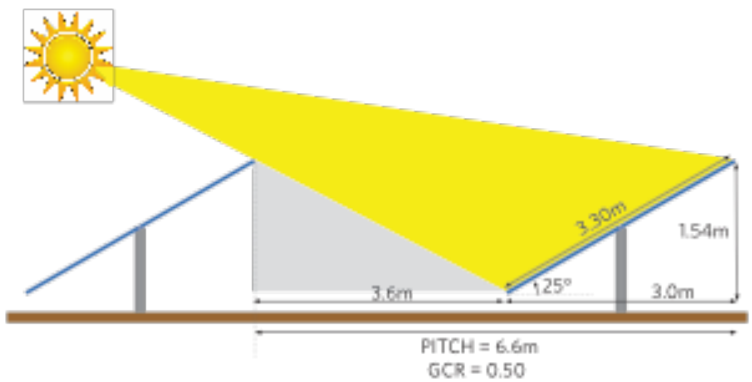
A typical shade derating plot is shown below. Note that when the ground coverage ratio is increased (corresponding to tighter row pitch) the energy production can drop off sharply for conventional solar panels.



As indicated by the gray arrow, Maxim's Solar Cell Optimizers enable the same energy production per panel at higher ground coverage ratios and tighter row pitches. This improved performance can have a significant impact on the investment return (ROI) because fixed project costs are amortized over a higher energy production. The enhanced performance also generally allows space-constrained arrays to provide more energy with minimal to no increase to LCOE. In fact, improving panel density can lower both LCOE $/kWh and upfront $/W capital expenditure. The exact savings depends on density improvement and a project's fixed versus variable cost components.

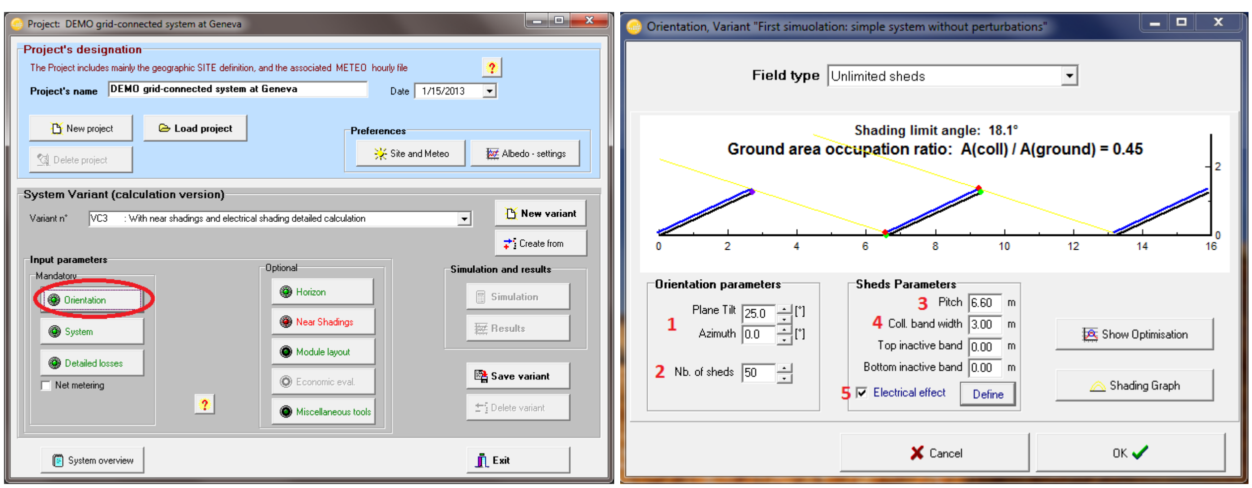
The general concept of row shade loss is easily understood when considered in the context of PVSYST modeling parameters. For example, the case of 2-up portrait racking (i.e., implying that panels sit in the portrait orientation stacked two high per row) is shown in the diagram below.





In this example, any sun angles lower than 23° will cause a shadow to be cast on the bottom row of the PV panels. With most PV arrays in the northern hemisphere facing due south, shadow-casting sun angles can be found in both the morning and afternoon "production hours."

In PVSYST, this effect is modeled within the Orientations setting using a feature called Unlimited Sheds.



Screenshot taken from PVSYST, licensed from PVsyst SA.

Several settings in the Unlimited Sheds configuration window are critical for proper modeling of row-to-row shading:

1. **Plane Tilt and Azimuth**

   Plane tilt refers to the angle of inclination of the panels, commonly referred to as "tilt angle."

Azimuth refers to the angular direction that the panels are facing, with 0° indicating due south for the northern hemisphere.

2. Nb. of Sheds

   Number of sheds refers to the number of rows in the fixed-tilt array. A small number of rows is impacted by the first row. This row is, by definition, unshaded as there is no row in front of it. As the number of rows increases, the effect of a completely unshaded first row becomes negligible.

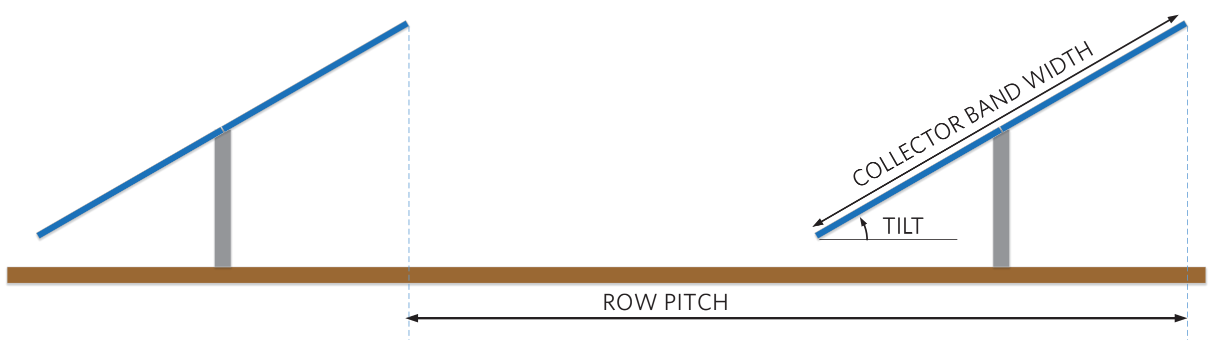
3. Pitch

   Pitch refers to the repetitive spacing between rows. Take care not to mix this with row spacing which is also commonly used. Row pitch refers to the distance from the front of a panel in one row to the front of a panel on the next row.

4. Coll. Band Width

   Collective band width refers to the active height of the panel (or stack of panels), which is dependent both upon the panel dimensions and the racking orientation and stacking. In our example, we assume 2-up portrait. Therefore, if the panel is 1.65m x 1.0m, then each panel is oriented to stand 1.65m tall and the collector bandwidth is 1.65m x 2 = 3.30m.

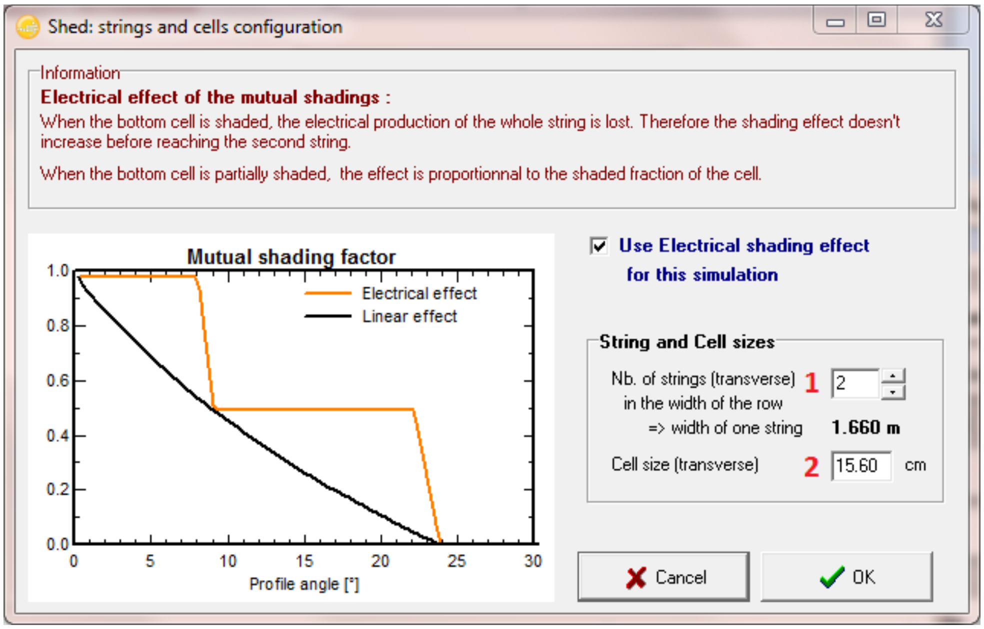
   If a 3-up landscape racking were used, then this parameter would be set to 1.0m x 3 = 3.0m



5. Electrical Effect

   The Electrical Effect box should be checked and details added by clicking on the Define button.

   When the Define button is clicked, the following configuration window appears.



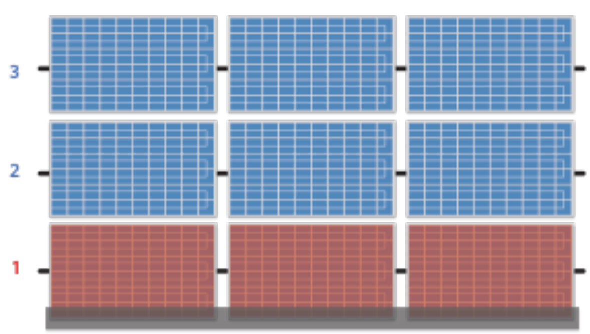
Screenshot taken from PVSYST, licensed from PVsyst SA.

Parameters for this window should be set as follows:

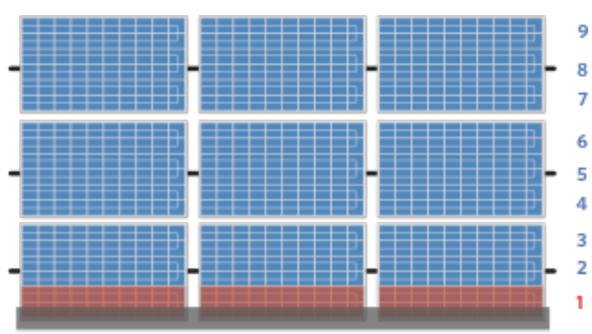
I. **Nb. of strings (transverse)**

With conventional panels, if one of the cell strings is shadowed then the entire electrical region or string is impacted. Stacked panels wired in series can be modeled as electrically independent from each other. Panels using Maxim's Solar Cell Optimizers provide electrical independence at the cell-string level, so the number (Nb.) of strings should be increased accordingly.

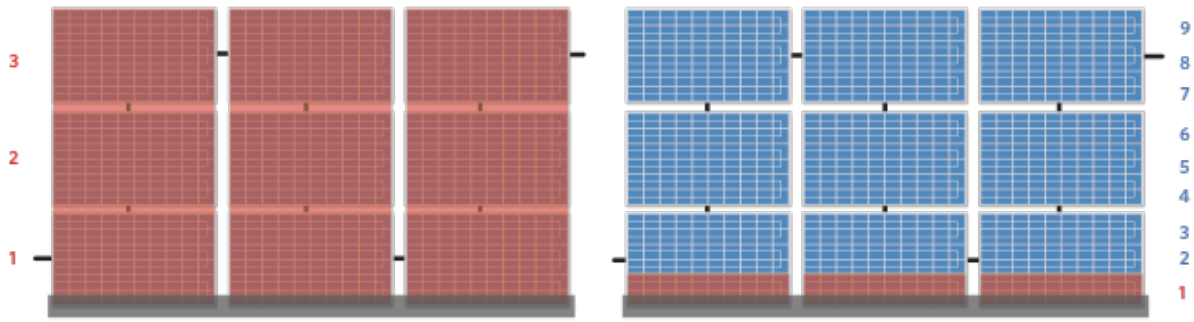
For example, the 3-up landscape racking examples below should be modeled by setting the number of electrical regions to 3 for the conventional array and 9 for the VT8020 array.



ELECTRICAL REGIONS FOR CONVENTIONAL PANELS IN 3-UP LANDSCAPE WITH PARALLEL WRITING



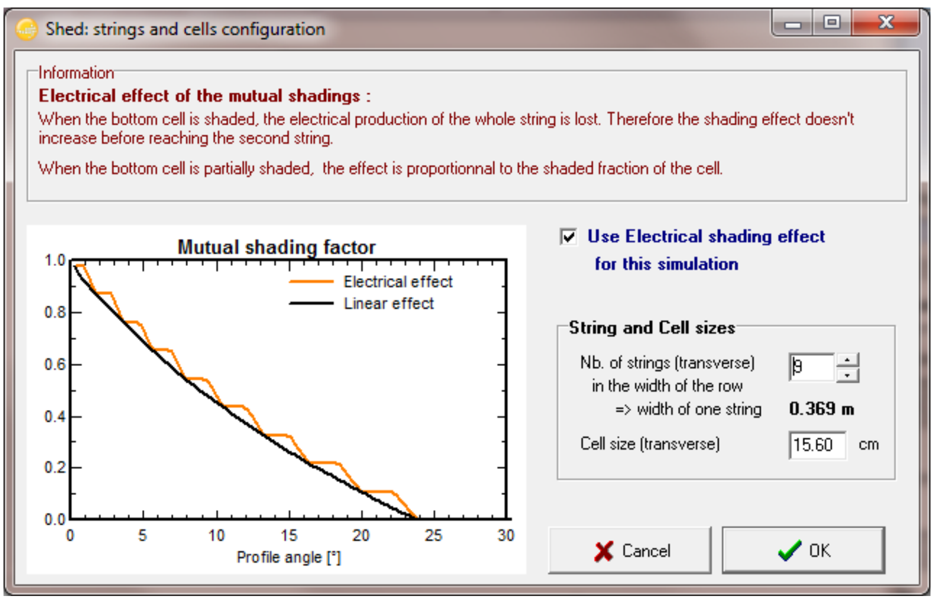
ELECTRICAL REGIONS FOR VT8020 PANELS IN 3-UP LANDSCAPE WITH PARALLEL WRITING



ELECTRICAL REGIONS FOR CONVENTIONAL PANELS IN 3-UP LANDSCAPE WITH SERIES WRITING

ELECTRICAL REGIONS FOR VT8020 PANELS IN 3-UP LANDSCAPE WITH SERIES WRITING

This cell-string VTB020 optimizer benefit can be modeled in PVSYST with a simple parameter change. By setting the number of strings in the above example to 9, the tool captures a good portion of the performance benefits.



Screenshot taken from PVSYST, licensed from PVsyst SA.

In fact, this method is quite conservative because it still models each electrical region as if protected with a bypass diode (e.g., all or no binary power production). With an optimizer dedicated to each cell string, however, any diffuse light exposed to each cell string is converted to output energy. The impact of this approach can be significant, depending on the relative magnitude of direct and diffuse light sources.

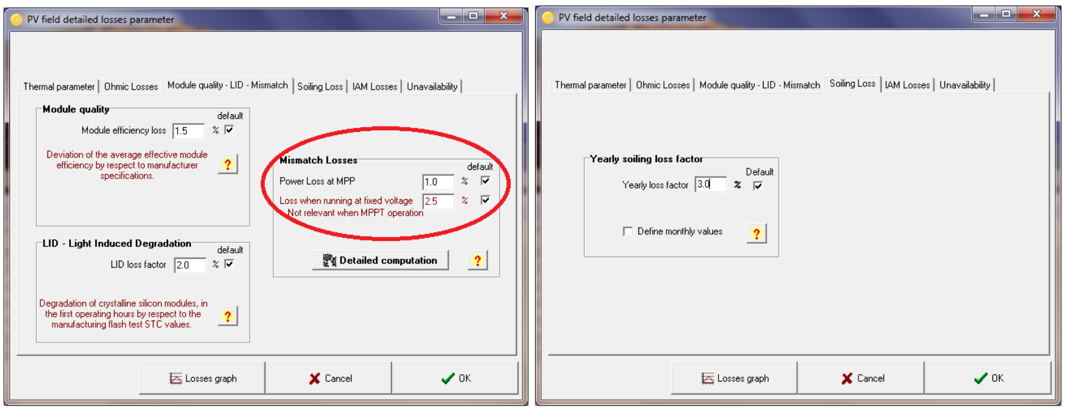
II. Cell size (transverse)

Be sure to enter the appropriate cell dimension for the panel being modeled. The standard cell size for most panels in production is 15.6cm.

3. Modeling Mismatch Losses

PVSYST merges all panel-to-panel mismatch into one parameter called Power Loss at MPP. The systems incorporating the Maxim Solar Cell Optimizer will incur no losses from panel-to-panel mismatch, so this value (and then one below it) should be set to 0%.

Furthermore, effects such as LID can vary significantly from panel-to-panel and cell string to cell string. Direct data is not available to quantify, but technically and practically speaking these degradation mechanisms are minimized and should be reflected when running simulations compared to other panel types.



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The impact of soiling losses can vary from panel to panel and cell string to cell string, especially in low-tilt applications common on commercial and residential rooftops. It is suggested that designers consider these benefits when entering loss estimates in a comparison between conventional panels and those outfitted with Maxim's Solar Cell Optimizers.

4. Performance and Modeling Validation

A side-by-side comparison of VT8012 modules and corresponding conventional modules has been operating since November 2012. The racking configuration is 1-up portrait, installed with a tilt of 30° and azimuth of 230°. DC performance is monitored with 0.1% accuracy for panel-level voltage and string-current measurements.

Test Site Details

- Tilt: 29.5°
- Azimuth: 230°
- GCR: 0.54
- Racking: 1-Up Portrait
- Inverter: PVI-6000

Reference Strings

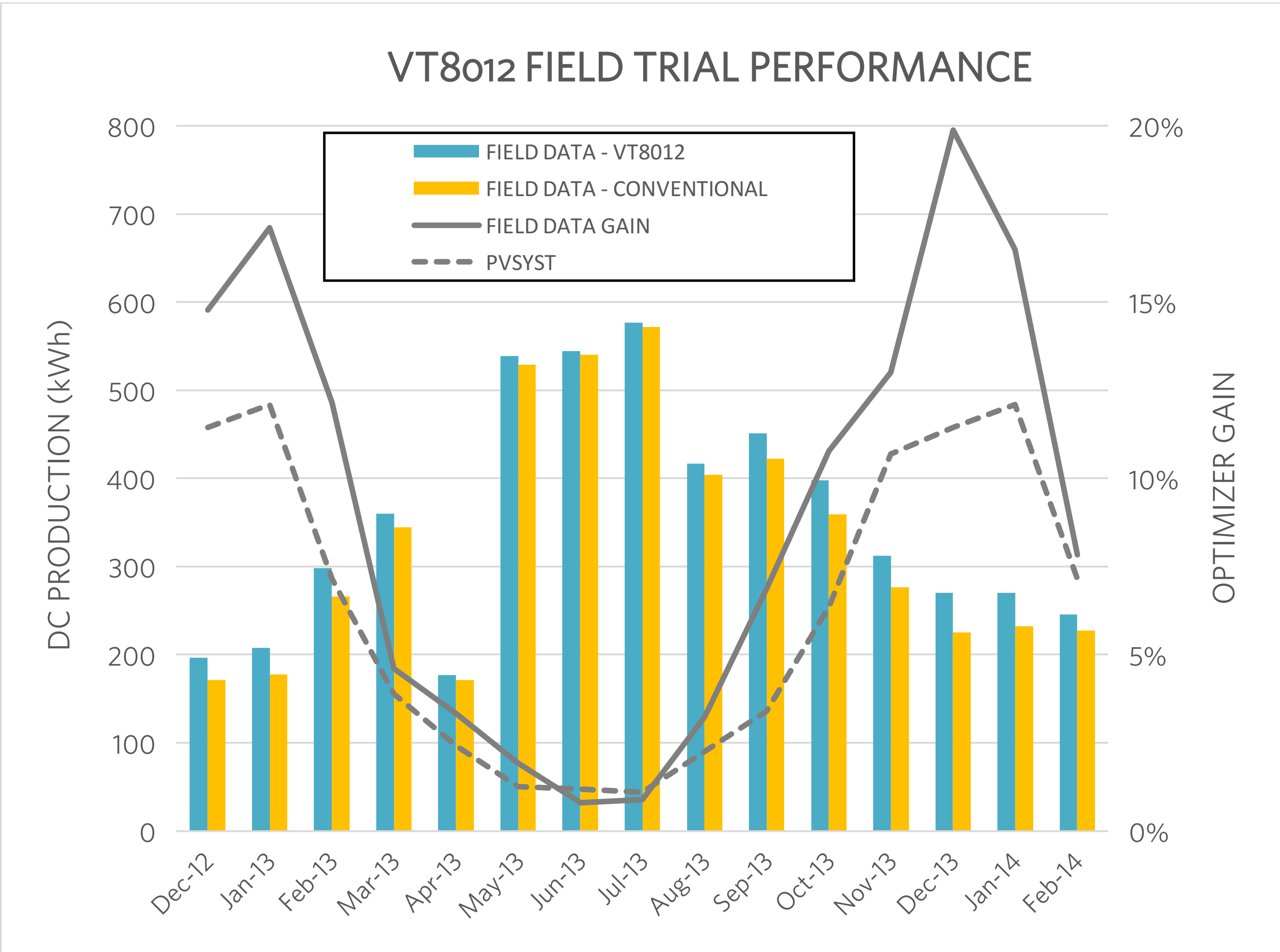
- Optimizer Type: none
- Panel DC Power: 250W
- Panels per String: 12
- Number of Strings: 2
- Total Power: 6.0kW

Test String

- Optimizer Types: VT8012
- Panel DC Power: 250W
- Panels per String: 12
- Number of Strings: 2
- Total Power: 6.0kW

Ongoing field data (i.e., DC production) is collected and compared to PVSYST modeling estimates.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
CONVENTIONAL	178	266	344	171	529	540	572	404	422	359	276	225	4286
MAXIM	208	298	360	177	539	545	577	417	451	398	312	270	4552
GAIN	+17%	+12%	+5%	+3%	+2%	+1%	+1%	+3%	+7%	+11%	+13%	+20%	+6.2%
PVSYST	+11%	+12%	+7%	+4%	+2%	+1%	+1%	+1%	+2%	+3%	+6%	+11%	+4.0%



The annualized performance improvement of the VT8012 panels was greater than 6%, outperforming the 4% estimate for a typical meteorological year (TMY) estimated by PVSYST.

We conclude from this case study that the PVSYST modeling methodology presented provides a conservative approach for determining the performance improvements achievable with Maxim's Solar Cell Optimizer solution.

5. Simulation Parameter Review

The following parameters within PVSYST can be set with appropriate values to model solar installations incorporating Maxim's Solar Cell Optimizers. Each of these parameters should be considered to fully realize the benefits attainable with Maxim's cell-string optimization technology.

Parameters affecting the accuracy of modeling with respect to ground coverage ratio and row-to-row shading are shown below.

PVSYST Parameter	Description
Collector Bandwidth	Active surface height of panels, including racking orientation and stacking
Electrical Effect	Option to include losses due to cell-string shading. Must be checked.
Number of Strings	Number of vertical independent electrical regions depends on panel, racking orientation, and stringing
Cell Size	Size of photovoltaic cells used in PV modules

Parameters affecting the accuracy of modeling with respect to ground coverage ratio and row-to-row shading are shown below.

PVSYST Parameter	Description
LID	Loss mechanism assigned to LID degradation. Impact reduced by Maxim Optimizers
Mismatch	Loss mechanism assigned panel-to-panel mismatches. Impact eliminated by Optimizers
Soiling Losses	Loss mechanism assigned to soiling. Impact reduced by Optimizers

6. Conclusion

This document presents a methodology for using PVSYST simulation software to estimate the performance characteristics of solar modules that incorporate Maxim's Solar Cell Optimizer technology. Particular emphasis is placed on the proper modeling of the row-to-row shading effect found in practical, fixed-tilt array designs. This methodology allows a PV engineer to design solar plants with aggressive ground coverage ratios. The methodology will also exhibit little to no impact on the specific yield of the Maxim-enabled panels relative to their conventional or panel-level optimized counterparts.

More Information

For Technical Support: http://www.maximintegrated.com/support
For Technical Support: http://www.maximintegrated.com/support
Other Questions and Comments: http://www.maximintegrated.com/contact