Bigger is Better: Sizing Solar Modules for Microinverters

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SUMMARY

This study analyzed the impact of using high power solar modules with the M215 Microinverter in 15 different installation scenarios. The analysis demonstrated that using larger module sizes significantly improves annual energy production, even while inverter size remains unchanged. Gains in annual production were 25-100 times more significant than the losses associated with inverter saturation. This suggests that applying high power solar modules to microinverters leads to greater lifetime performance, lower installed cost per watt, and ultimately, the highest return on investment for the end-customer.

INTRODUCTION

Solar module output is a complex phenomenon that depends on many, fluctuating factors, such as sunlight, temperature, wind speed, optics (glass clarity, dust and soiling), and more. Yet, despite its variability, module output is consistent in one way: it's almost always less than the nameplate rating of the module. In fact, module output rarely exceeds 90% of the module's nameplate rating.

Due to the significant discrepancy between module nameplate ratings and actual field performance, system designers are faced with a difficult question: *How should I size the downstream components of the system?*

Sizing downstream components to match the module's nameplate rating is almost guaranteed to result in excessive cost to the end-customer. Conversely, while selecting smaller downstream components will lower the system cost, it can also limit the output of modules at select times, when conditions are optimal. Thus, it's important to develop guidelines for component selection that balance cost with performance.

This paper evaluates the impact of using different module and microinverter sizes on system cost and performance, in a variety of climates and installations.

METHODOLOGY

Modeling Microinverter Behavior

Using Enlighten™, Enphase's web-based solar monitoring software, the output behaviors of installed microinverters were analyzed in multiple locations across the U.S., each with DC:AC ratios above 120%. The output characteristics were then compared to solar irradiance measurements from nearby weather stations to establish a performance ratio (PR) between incoming solar irradiance and outgoing AC power.

At times when the inverter was saturated (module output exceeded the M215 Microinverter's maximum output power of 225W), the PR was assumed to be constant relative to values recently observed (Fig. 1). [NOTE: This is a conservative assumption for modeling the energy lost to inverter saturation, considering that higher irradiance levels typically correlate with higher temperatures, which adversely affect module performance, and thus, should slightly decrease the PR at times of high irradiance.]

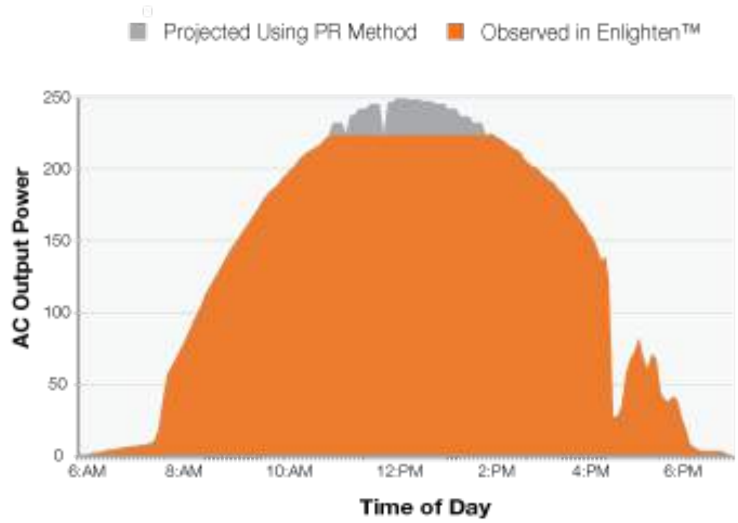

Figure 1: A single-day of output for an M215 paired with a 260W module is shown in orange. In grey, the projected behavior based on the PR method is shown.

Using the PR method, the effect of different module sizes can easily be estimated by adjusting the output in proportion to the module's power. For example, if a 240W module produced 212W at a given irradiance level, then a 280W module would produce approximately 247W at the same irradiance level.

Figure 2 illustrates an example of three different module powers being modeled for a single day.

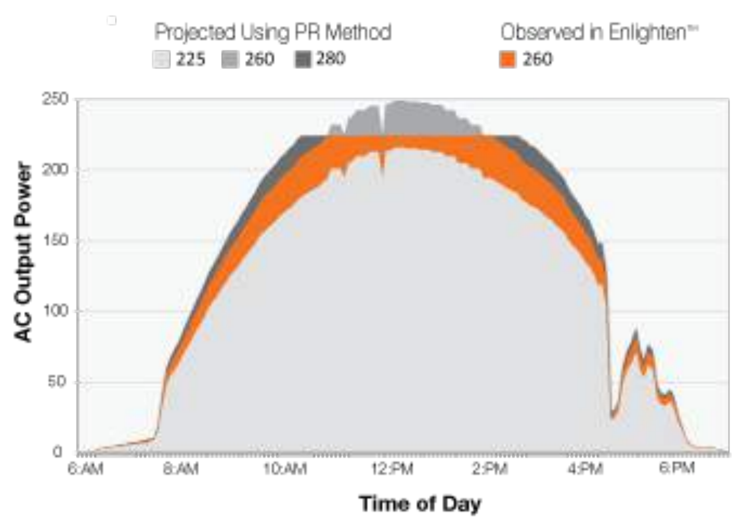

Figure 2: Using the PR method, the behavior of multiple module sizes on a single day is shown in grey. Inverter saturation behavior is shown above the M215's maximum output power of 225W.

Modeling Annual Impact

To estimate the impact of module and microinverter sizes on annual energy production, the PVsyst performance modeling software was used. Adjustments were made to the default parameters in PVsyst to align its predictions with values observed in Enlighten™. Alignment between PVsyst and the observed data was confirmed using the same weather files and installation locations as with the PR method. Table 1 shows the adjustments made to modeling parameters in PVsyst.

Once adjusted, PVsyst was used to model annual performance in multiple geographic locations and at multiple tilt angles, all using default meteorological files in PVsyst. In total, 15 PVsyst simulations were performed, and for each, 8 module sizes were analyzed using the PR method. Table 2 explains the variables used in all 120 scenarios.

The impact of inverter saturation was analyzed by limiting the hourly PVsyst predictions to the microinverter's maximum output rating. In the case of the M215, the maximum output was 225W; for the theoretical microinverter rated at 240W, the maximum output was assumed to be

250W. The difference between the original PVsyst prediction and the inverter-limited value was considered the loss to inverter saturation.

It should be noted that these simulations did not include annual module degradation. It is reasonable to expect that module degradation would reduce the impact of inverter saturation, meaning that this analysis is conservative within the context of lifetime performance.

Table 1: Adjustments made to parameters within the "Detailed Losses" section of PVsyst.

Parameter Name	Value	Description
Thermal Parameter	“Free”	Assumes good airflow (lower temp.) for module
Ohmic Loss	0.0%	Assumes no wire loss from module to microinverter
Module Efficiency Loss	-1.0%	Assumes positive manufacturing tolerance of +1.0%
Module Mismatch	0.0%	Assumes no mismatch effects within the array
Soiling Loss	0.0%	Assumes no light is blocked by dust or dirt

Table 2: PVsyst simulations were performed to address all combinations of these design factors.

Location	**Tilt** (deg.)			**Module Size** (Watts @ STC)							
Los Angeles, CA	20	30	40	250	255	260	265	270	275	280	285
Toronto, ON	20	30	40	250	255	260	265	270	275	280	285
Denver, CO	20	30	40	250	255	260	265	270	275	280	285
Newark, NJ	20	30	40	250	255	260	265	270	275	280	285
Phoenix, AZ	20	30	40	250	255	260	265	270	275	280	285

RESULTS

Annual Impact

Overall, annual losses to inverter saturation were insignificant. In 90% of the scenarios using the M215 Microinverter, including all scenarios with module nameplate ratings below 275W, annual losses were less than 0.5% (Table 3). Conversely, increasing module size resulted in significant gains in annual production, even while inverter size remained unchanged.

As can be seen in Figure 3, increasing module size had a nearly linear benefit to annual production, resulting in gains that were 25-100 times greater than the losses to inverter saturation. It's important to note, however, that annual losses to inverter saturation increased geometrically with module size, and at a certain point, the marginal losses would begin to exceed the marginal gains. This crossover typically occurs above 140% DC-to-AC ratio, or when pairing >300W modules with an M215 microinverter.

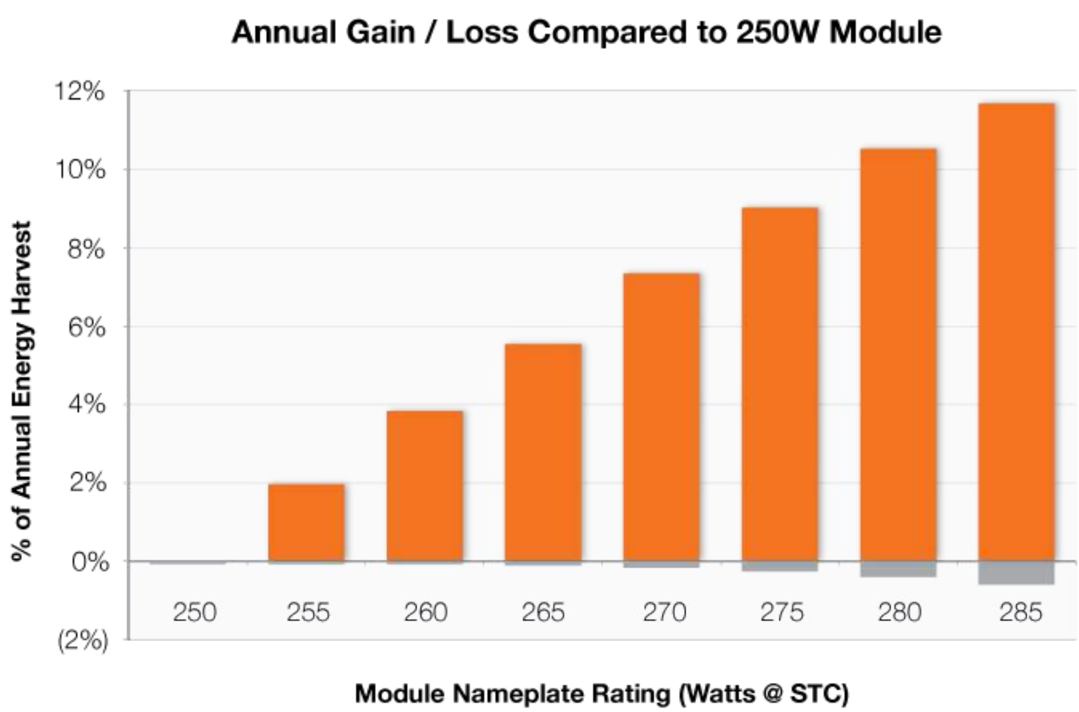

Figure 3: The annual performance gain for different module sizes, relative to a 250W module in Denver, CO, is shown in orange. Total annual losses to inverter saturation are shown in grey.

Microinverter Behavior

In all scenarios, the M215 Microinverter was operating below its maximum output for more than 90% of the year. Figure 4 shows the total hours that the M215 spent throughout the year at each output power level, when paired with a 260W module in Denver, CO. As can be seen, the microinverter operated below its maximum output rating for more than 99.5% of the year.

To assess the impact of inverter saturation, it's important to remember that the inverter continues to output at its maximum power rating during these times (Figure 1). For example, in

Figure 4, the inverter continued to produce 225W during the "Inverter Saturation Hours", and as a result, it converted approximately 95% of the module's total output during these hours.

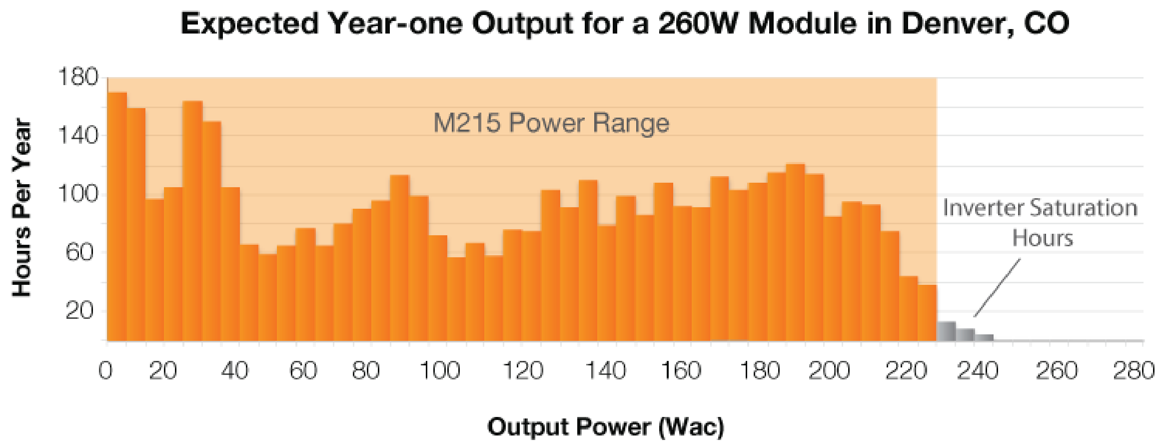

Figure 4: The distribution of hours spent at each output power level throughout the year by a 260W module in Denver, CO at 30 degrees tilt. Inverter saturation hours are shown in grey.

As can be seen in Table 2, location influenced the losses to inverter saturation. This is explained by the fact that certain locations are more likely to have sunny conditions at low temperatures. Typically, these are locations at high altitude or high latitude.

Similarly, we see in Table 5 that high tilt angle led to more inverter saturation because cold temperatures and high irradiance are more likely to occur when the sun is low in the sky (either early in the day or during winter months). Conversely, it is likely that any tilt angle less than 20 degrees will result in a negligible amount of energy loss to inverter saturation.

Table 5: The annual energy loss from inverter saturation is shown for 120 different installation scenarios.

Location	Tilt (deg.)	Annual Loss to Inverter Saturation							
		Module Sizes (Watts @ STC)							
		250	255	260	265	270	275	280	285
Los Angeles, CA	**20**	0.00%	0.00%	0.00%	0.01%	0.02%	0.04%	0.07%	0.13%
	30	0.00%	0.00%	0.01%	0.02%	0.03%	0.07%	0.13%	0.23%
	40	0.00%	0.00%	0.01%	0.04%	0.09%	0.16%	0.25%	0.37%
Toronto, ON	**20**	0.01%	0.03%	0.05%	0.09%	0.16%	0.25%	0.38%	0.53%
	30	0.04%	0.07%	0.12%	0.19%	0.30%	0.43%	0.60%	0.80%
	40	0.10%	0.16%	0.23%	0.32%	0.43%	0.58%	0.75%	0.96%
Denver, CO	**20**	0.00%	0.00%	0.01%	0.02%	0.04%	0.08%	0.16%	0.27%
	30	0.00%	0.01%	0.03%	0.07%	0.13%	0.23%	0.37%	0.56%
	40	0.04%	0.08%	0.14%	0.22%	0.34%	0.49%	0.68%	0.90%
Newark, NJ	**20**	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.03%	0.07%
	30	0.00%	0.01%	0.01%	0.02%	0.04%	0.07%	0.11%	0.17%
	40	0.01%	0.03%	0.04%	0.07%	0.11%	0.16%	0.23%	0.31%
Phoenix, AZ	**20**	0.00%	0.00%	0.01%	0.03%	0.07%	0.13%	0.22%	0.34%
	30	0.00%	0.00%	0.04%	0.09%	0.16%	0.28%	0.45%	0.66%
	40	0.02%	0.04%	0.10%	0.20%	0.34%	0.54%	0.78%	1.06%

Economic Impact

In all cases, the installed cost per watt declined as the module size was increased (Figure 5). This is explained by the fact that module cost was only a fraction of the total system cost, yet module size was the entire basis of system size. Thus, the denominator in the cost per watt equation increased faster than the numerator.

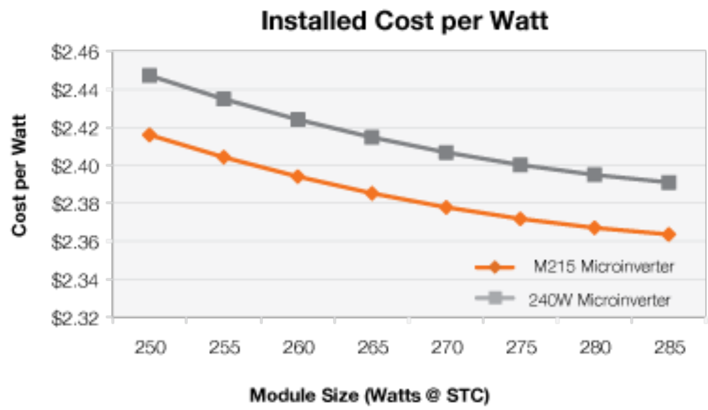

Figure 5: Installed cost per watt is shown for different module and microinverter sizes.

Conversely, increasing the microinverter size increased the system cost, but had no affect on system size. Thus, the cost per watt of the system was consistently higher when using a larger microinverter. It's important to note that this effect could become more significant if the higher microinverter capacity also required increases in the size and cost of electrical components.

Figure 6: Expected rate of return is shown for different module and microinverter sizes.

From an investment standpoint, the system's rate of return increased with module size, but not microinverter size. This is consistent with the finding that the gains from increasing module size were more significant than the losses to inverter saturation. Thus, the value of additional production from using larger modules was greater than their additional cost, but the value of additional production from using a larger microinverter was not.

Figure 7 directly compares the additional cost of the 240W microinverter to the value of additional production. Though the value of using a larger microinverter increased as module size increased, this value, in all cases, was less than the additional cost of the larger microinverter.

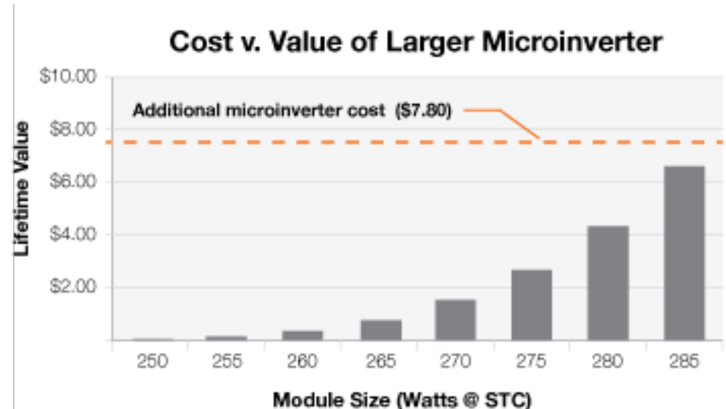

Figure 7: The additional value of a larger capacity microinverter is compared against the additional cost.

CONCLUSION

It is clear from this study that using high power solar modules with the M215 Microinverter results in substantial gains in annual production and minimal losses to inverter saturation. This conclusion is furthered by the fact that lifetime losses to inverter saturation will likely be lower, due to module degradation and increased soiling over time.

This study highlights the need to evaluate solar modules based on their expected field performance, rather than their nameplate rating. Solar modules will only perform to their nameplate rating during select weather conditions, when the sun shines brightly and the temperature is cold. Overall, these conditions are rare, only occurring on a small percentage of days in the late winter and early spring. Whereas, most sunny days throughout the year have higher temperatures, which typically reduce the module's output to 80% or less of its nameplate rating.

In addition, this study has shown that there are substantial cost savings associated with applying high power modules to the M215 Microinverter. This finding is significant within today's industry environment, where solar module prices are declining rapidly and the cost of microinverters and electrical equipment is an increasingly important portion of system cost. These trends suggest that the optimal module-to-inverter sizing ratio will continue to increase over time, encouraging system designs that frequently saturate the microinverter's capacity due to its favorable impact on return on investment.