MEASURING THE EFFECT OF MODULE-LEVEL POWER ELECTRONICS ON SOFT COSTS

SOLARBRIDGE TECHNOLOGIES™

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Executive Summary

In the cost-sensitive and competitive residential PV installation business, installers are searching for new ways to reduce costs and stay a step ahead of the competition. The method most commonly used has been to put a nearly exclusive focus on reducing hardware costs. But as PV system hardware costs have begun to stabilize, savvy installers are starting to analyze the soft costs that underlie their business operations and ask themselves: Can my selection of PV system power electronics have a "hard effect" on soft costs?

"SolarBridge TrueAC modules reduce total soft costs by 33%."

Reports published in 2013 by the Rocky Mountain Institute and NREL sought to better understand soft costs and revealed that using AC modules instead of string inverters in average residential installations could reduce soft costs by 50%.[1,2] To expand on those findings, SolarBridge Technologies conducted a national survey of installers using AC modules (a factory integrated microinverter and PV module) and other power electronics to verify this unprecedented opportunity to reduce soft costs. SolarBridge asked installers to provide comparisons in installation labor, total installation time and customer acquisition experiences. The responses were then compared to the string inverter data in the RMI and NREL reports.

The results were impressive. Installers reported that using SolarBridge TrueAC™ systems saved installation labor costs by reducing overall time required to complete an installation and by reducing the number of site visits required. The installers confirmed that SolarBridge TrueAC ACPV modules reduced their total soft costs in a residential PV system by an average of 33%.

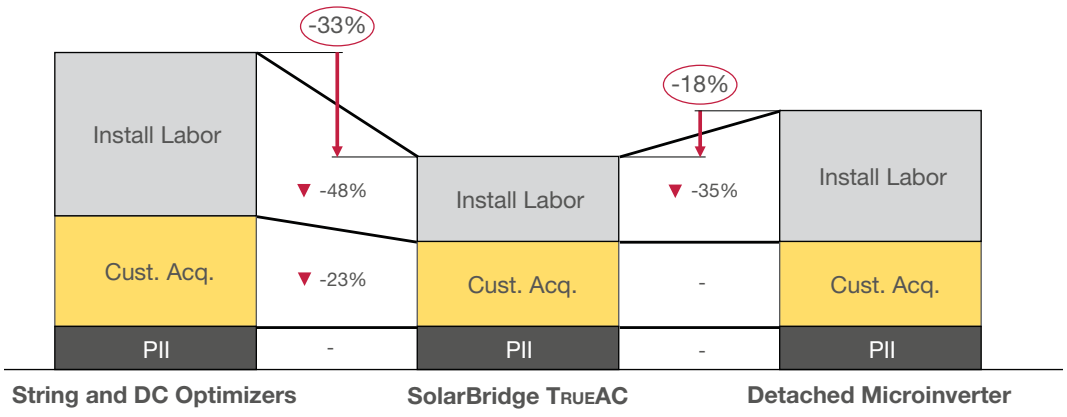

FIGURE 1 TrueAC Yields the Most Soft Cost Savings

[1] Morris et al., *Reducing Solar PV Soft Costs: A Focus On Installation Labor* (RMI, GTRI, December 2013):6
[2] Ardani et al., *Non-Hardware ("Soft") Cost Reduction Roadmap for Residential and Small Commercial Solar Photovoltaics, 2013-2020* (NREL, August 2013)

Introduction

It's an exciting time to be in the residential PV business in the United States. In the first quarter of 2014, and for the first time since early 2010, more MWs of PV were installed in residential systems than in commercial systems. In Q2, the impressive growth in residential PV installations continued with a 44% increase in MWs installed compared to Q2 2013.[3] It is easy to argue that the growth can be attributed to the improved affordability of solar through the rapid decline in the cost of residential PV systems.

A 2013 report from Lawrence Berkley National Labs found that from 2008 to 2012, U.S. residential system costs decreased 37%, and 80% of that decline was from reduced PV module costs.[4]

However, the decline in PV module costs is not expected to continue. PV system hardware costs are still falling, but at a decreasing rate. The cost of PV modules is leveling out[5] or slightly increasing. At the same time there is increasing competition among installers as the industry seeks to achieve the Department of Energy 2020 SunShot program installed cost goal of $1.50/W[6]. Lower PV module and other hardware costs may help reach that goal, but they won't be enough. To stay competitive, residential PV installers will have to look beyond the cost of hardware and start to analyze all the costs of installation, including the soft costs.

Hardware costs are easily understood. Soft costs, best described as those costs that are not hardware related, is a relatively new topic of discussion. Soft costs are estimated to account for 69% of the total installed cost of a US residential PV system[4]. A recent Rocky Mountain Institute and Georgia Tech Research Institute report compared soft costs in the United States to those in Germany, a more mature solar market. The report revealed that soft costs in Germany are 73% lower than those in the United States[7]. That number shows that there is significant opportunity to reduce soft costs in US installations.

There is more to controlling soft costs than just good management and more experienced crews. The studies found that the type of PV system electronics selected for an installation can have an impact on soft costs and therefore on total system costs. Installers should ask themselves not just what their hardware costs are, but how their inverter choices are affecting other costs in their installations and in their businesses.

The previously mentioned Rocky Mountain Institute report *Reducing PV Soft Costs: A Focus on Installation Labor* and an NREL report *Non-Hardware ("Soft") Cost Reduction Roadmap for Residential and Small Commercial Solar Photovoltaics* identified sources of soft costs in string inverter-based systems. The report focused on costs which have feasible opportunities for reduction, including process inefficiencies, on-site labor and customer acquisition. The report also proposed opportunities to eliminate those costs. Upon review of these reports, SolarBridge found that a number of the recommendations to reduce soft costs, such as AC module integration and reducing the number of days to complete an installation, are already being realized by installers of SolarBridge TrueAC modules. An initial estimate showed that, based on the cost reduction roadmaps in these RMI and NREL reports, installers using SolarBridge TrueAC modules could reduce soft costs by as much as 50% as compared to installing a string inverter.

SolarBridge sought to confirm this exceptional soft cost savings benefit by surveying experienced installers across the country. Our objective was to determine whether installers using ACPV modules are experiencing this level of soft cost savings and to determine what the comparative soft cost expense is for systems using detached microinverters such as Enphase and string inverters with DC optimizers such as SolarEdge. This article shares the results and conclusions from this research effort.

What is a TrueAC module?

In a SolarBridge TrueAC module, a microinverter is factory integrated with a PV module, resulting in an appliance that natively produces AC power. The entire module is certified as an AC module and protected by an end-to-end, 25-year warranty. Using the integrated AC cabling of the microinverter, TrueAC modules are connected together to form an ACPV system.

How is it different from a microinverter?

In a SolarBridge TrueAC system, the inverter and module have been selected by the module manufacturer and SolarBridge for optimized pairing. The two are assembled in a factory environment where DC connections and the inverter-to-module grounding connection are tested using repeatable and quality-verified methods. This results in a uniquely safe and optimized AC appliance which cannot be matched or verified by a module and inverter pairing done at an installation site.

FIGURE 2 SolarBridge TrueACModule

A SolarBridge TrueAC module eliminates the need for the additional installation steps required by detached microinverters. With integral AC cabling and native AC output, TrueAC simplifies system design, allowing any number and combination of modules to connect directly to the grid. The elimination of exposed DC wiring, DC arc faults and all high-voltage DC balance of systems enhance installer and firefighter safety. An ACPV system with TrueAC also includes inherent rapid shutdown capability.

[3] Honeyman et al., *U.S. Solar Market Insight Report Q2 2014* (GTM Research, September 2014): 6.
[4] Wiser et al., *Tracking the Sun VI* (LBNL, August 2013): 13–15.
[5] Barbose et al., *Tracking the Sun VII* (LBNL, September 2014): 14.
[6] *Sunshot Vision Study* (US Department of Energy, February 2012):xix.
[7] Morris et al., *Reducing Solar PV Soft Costs: A Focus On Installation Labor* (RMI, GTRI, December 2013): 9.

TrueAC Module Certification and Testing

A SolarBridge TrueAC module is certified as an AC module through two UL standards, UL1741 and UL1703. UL1741 is a common standard that all inverters must go through; UL1703 certification of power electronics is unique to AC modules. The process of AC module certification begins with the evaluation of the DC PV module to UL1703, the standard by which all DC modules are evaluated when sold in the United States. The SolarBridge microinverter is certified to UL1741, the standard by which all grid-tie inverters must be evaluated, and then is subjected to the environmental tests of UL1703. Finally, the microinverter and DC module are evaluated and certified together as an AC module under UL1741. The resulting factory assembled and certified AC module is code compliant, safe and extremely easy to install.

Following certification, and as part of their microinverter selection process, DC module manufacturers subject the microinverter to a series of tests as part of their evaluation. The SolarBridge microinverter is subjected to the same extreme environmental and electrical tests that DC modules go through during development.

Finally, an inclusive 25-year warranty for the module and microinverter provides peace of mind to both the system owner and installer. This one warranty eliminates the need for the system owner to track and maintain multiple warranties, thus providing an extra layer of simplicity and comfort.

What are soft costs?

Soft costs are non-hardware related costs incurred during the installation of a PV system, only some of which are directly related to the installation. Soft costs related to financing, installer margin and taxes are not affected by the selection of power electronics in a system. However, three primary soft cost categories can be directly affected negatively or positively by an installer's selection of power electronics within a system. They include:

1 .installation labor costs,
2. permitting, inspection, & interconnection costs
3. customer acquisition costs.

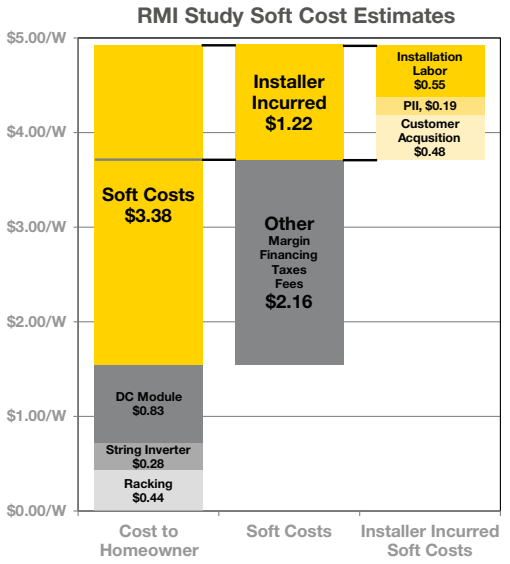

FIGURE 3 Soft Cost Elements (courtesy Rocky Mountain Institute)

Installation Labor

Installation labor costs are the direct labor expense incurred during the process of the PV system installation, such as inverter mounting, module racking installation and unloading the truck.

Permitting, Inspection, & Interconnection (PII)

Permitting, inspection, & interconnection (PII) costs include the building permits, electrical and building inspection and utility interconnection required for an individual installation. Some of these costs can be spread across all installations that an installation company does over a year, while some costs vary with the installation type and size.

Customer Acquisition

Customer acquisition costs are related to identifying, engaging and closing sales with potential solar system customers. These costs are usually fixed and spread across all installations that an installation company does.

Soft costs are difficult to manage and may appear to be fixed in many cases. So it comes as a surprise to many installers that these costs could be influenced by their selection of power electronics.

Quantifying Soft Cost Benefits of TrueAC Modules

The studies conducted by RMI and NREL focused on string inverters and did not attempt to explore the impact of power electronics selection on the soft costs in an installation. However, the studies do provide a complete breakdown of soft costs for string inverter systems. SolarBridge sought to build on this survey data for string inverters and create a comparable estimate for the soft costs associated with the installation of SolarBridge TrueAC modules, detached microinverters and the combination of a string inverter and DC optimizers. To do this, we asked installers to tell us their real-world experiences.

SolarBridge surveyed 32 installers in 16 key solar states across the country (see Fig. 4) asking about their experiences with labor costs and customer acquisition

FIGURE 4 Map of Survey Respondents

costs associated with each type of power electronics. Survey participants were randomly selected from a master list generated from publicly available lists of solar installers and Internet searches. Participating installers were required to have direct hands-on experience or close knowledge of installation of a string inverter and module level power electronics. We also asked that they have an understanding of sources of customer acquisition costs for a system. We chose not to focus on the permitting, inspection and interconnection element of soft costs due to the variability in those costs from jurisdiction to jurisdiction regardless of power electronics used.

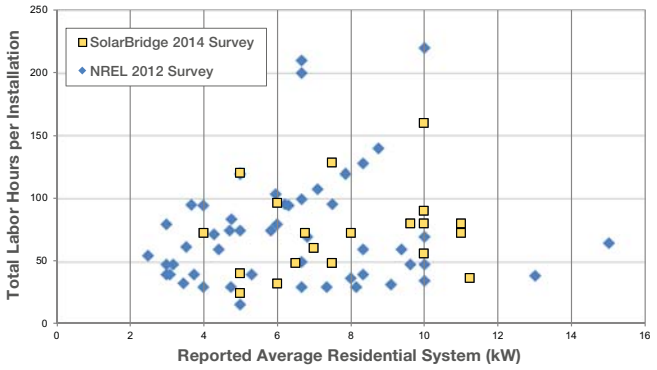

FIGURE 5 Comparing SolarBridge and NREL Survey Responses

The survey data were then compared to the data provided by the RMI and NREL studies, and average national cost estimates were calculated as differences from the string inverter baseline. To validate our results, we compared our labor cost findings against the findings from the NREL and RMI reports and found a strong correlation. Follow-up discussions with representatives from Georgia Tech and the Rocky Mountain Institute indicated that the SolarBridge approach to the study is valid and that our responses were statistically significant.

ACPV Lowers Installation Labor Costs

The SolarBridge survey found that SolarBridge TrueAC systems save installation labor cost by reducing overall time to complete an installation and by reducing the number of site visits required for an installation. For an average 5kW residential system, using TrueAC modules reduce total labor costs by 33% compared to a string inverter, by 35% compared to an Enphase detached microinverter, and by an impressive 48% compared to a SolarEdge solution.

With a team of four, including two non-electricians and two electricians, the average installation time for a string inverter based residential system is 2.4 days. Survey respondents with relevant experience said using SolarBridge TrueAC modules reduced their installation time by an average of 24% compared to using string inverters in the same installation. The majority of installers with Enphase installation experience said that installing a system using detached microinverters took the same amount of time or more time than the same system using string inverters. In the worst case, SolarEdge installers experience a 19% average increase in installation time as compared to the same system using string inverters. When compared to the SolarEdge alternative, SolarBridge TrueAC saves installers 36% in installation time and 48% in total installation labor cost.

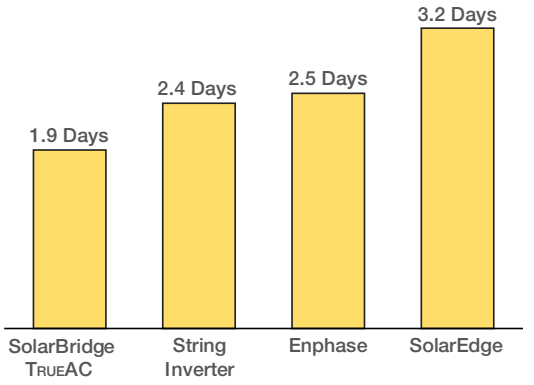

FIGURE 6 Average Number of Days to Install

TrueAC Labor Savings

- Factory integrated microinverter
- Fully integrated AC cabling
- No DC BOS installation
- Complete cable management
- Eliminated ground conductor
- Inherent rapid shutdown compliance
- Single product SKU for all installations
- No DC string sizing

According to installers, an average SolarBridge TrueAC residential system can be installed in 1.88 days by a crew of four instead of the 2.4 days required for a string inverter system – saving an entire site visit.

Data presented in the RMI study showed that a reduction in the number of days to complete an installation can by itself save $0.05/W on a system[8]. This $0.05/W is attributed to activities that are necessary but do not contribute directly to the installation such as loading and unloading supplies, travel time, preparing the site to begin work and cleaning up the site. TrueAC systems can be installed in fewer days, with fewer site visits, thus reducing installed cost by $0.05/W on every SolarBridge system installed.

Savings in Customer Acquisition Costs

Customer acquisition costs account for nearly 10% of the total price an average residential system[4]. These costs are based on what an installation company spends in total to attract new prospective customers. Consider that an installation company will incur fixed sales and marketing cost for the same numbers of systems are bid. A power electronics solution that enables a greater number of

[8] Morris et al., *Reducing Solar PV Soft Costs: A Focus On Installation Labor* (RMI, GTRI, December 2013): 6

those bids to be successful (higher conversion rate), especially if the systems are larger, has the net effect of reducing the customer acquisition cost per watt of PV systems installed. Using this logic, SolarBridge asked installers about the impact of TrueAC modules on the number of systems they were able to sell and whether the systems sold were larger.

Survey results among installers with experience with microinverters showed that 25% of the systems they sold would not have been economically feasible without the use of microinverters. That was either due to system sizes being overly restricted due to shading or other conditions that could not be addressed without the use of microinverters or TrueAC modules. We found during our survey that, without the use of TrueAC modules or microinverters, installers would have been forced to walk away from 25% of prospective installations.

TrueAC modules or microinverters eliminate considerations for individual module shading or maintaining a continuous DC string, and thus allow the flexible placement of modules on the roof. Through this unique flexibility value, TrueAC modules enabled 7% larger systems on average.

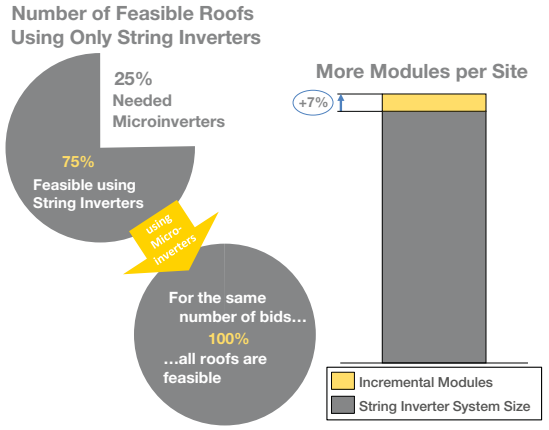

FIGURE 7 Reducing Customer Acquisition Costs with TrueAC Modules

The bottom line was that the combination of more successful bids and an increase in average system size allowed TrueAC installers to reduce customer acquisition costs by 22%.

Conclusions

With increased competition among US installers and stabilizing costs for PV system hardware, installers need to turn their focus to other areas of their business to reduce soft costs. SolarBridge TrueAC modules with integrated microinverters provides installers with an unmatched opportunity to reduce PV installation soft costs and be more competitive. SolarBridge TrueAC modules reduce total soft costs by up to 33%.

A survey of installers across the country confirmed that SolarBridge TrueAC ACPV save on soft costs more than any other inverter or optimizer solution and supported the conclusions of the Rocky Mountain Institute and Georgia Tech Research Institute report. Compared to string inverters, TrueAC modules reduce soft costs by 24%. Compared to DC-to-DC optimizers, SolarBridge TrueAC modules reduce those costs by 33%. And compared to detached microinverters, TrueAC modules reduce soft costs by 18%.

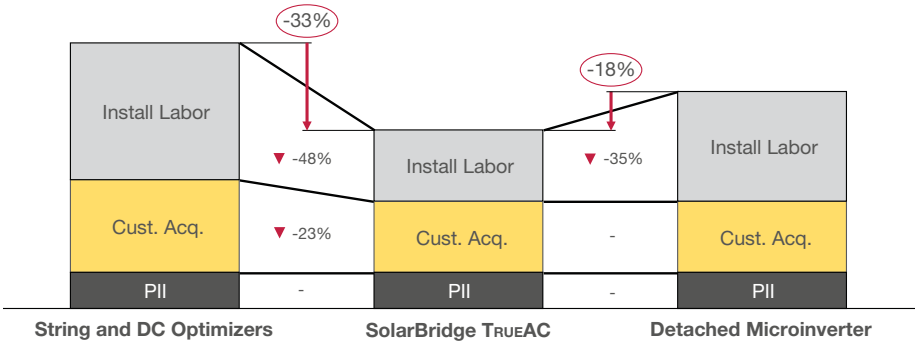

FIGURE 8 TrueAC Yields the Most Soft Cost Savings