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Pre-construction, engineering and design costs of large-scale residential installations – part 1

Angiolo Laviziano & **Ethan Miller**, REC Solar, San Luis Obispo, California, USA

ABSTRACT

PV industry module and component manufacturers have brought down costs significantly over the last four years. This trend is clearly evident as most publicly traded companies continue to increase revenue despite falling module and component prices. However, it is far less clear how downstream system integrators are handling the drop in system prices and contributing to value creation. System prices are generally higher in the U.S. than in Europe, despite lower module prices in the U.S. This disparity often raises questions on the part of European PV professionals where these costs come from, and secondly, what U.S. system integrators have done to reduce costs. This two-part series will shed light on how U.S. system integrators have undertaken tremendous efforts to decrease cost and add value through innovation by focussing on labour-intensive value creation in the downstream segment. Part I will focus on the residential market segment by delving into activity cost savings through innovation in engineering and construction, while Part II will illustrate how changes in sales, rebates, interconnection, and the supply-chain management over the last five years have reduced costs.

Competitive pressures along with falling rebates in the U.S. residential market have forced a focus on cost reduction through the value chain. While the largest cost reductions have been the cost of modules, there have been major improvements in engineering and construction. Both manufacturers and downstream integrators must continue to innovate as system installation volumes grow and subsidies continue to fall. For integrators, the best-known areas for improvement and innovation include system design, installation labour, and BOS components. Each of these areas will be explored in further detail in this paper.

System design

The most important paradigm shift occurring in residential system design today is a move away from the need for custom engineering. Rather than engineered individual projects, residential PV projects are increasingly pre-configured. Five years ago, residential projects were all custom engineered. The PV integration business is finally catching on to techniques and business practices used by other far more complex manufacturing businesses.

Primary areas of improvement in system design have been around site investigation, system layout, single-line drawings, bill of materials and permit-plan set creation. The shift to repeatable configuration requirements in the residential business has led to faster execution and cost savings through simplified skill set requirements for each design, as shown in Table 1.

A comparison of system design labour costs in 2005 versus 2010 shows how residential system integrators are driving toward a far leaner system design process. Labour time has been approximately cut in half. Engineering skills are no longer required for every step of the process, thereby reducing labour cost. Leading system integrators have been able to reduce the $/watt component by 57%, primarily through reduced system design requirements using improved design tools, standards and processes.

All systems start with some form of site investigation to determine the optimum system configuration that meets customer requirements. Significant efficiencies have been gained through the introduction of readily available improved satellite imagery, electronic shade analysis

	2005 hours/kW	$/Watt	2010 hours/kW	$/Watt
Site investigation	1.56	0.05	0.93	0.03
System layout	0.67	0.03	0.39	0.01
Single line drawing	0.40	0.02	0.23	0.01
Bill of materials	1.00	0.05	0.22	0.01
Permit plan creation	1.60	0.06	0.82	0.03
Total	5.22	0.21	2.59	0.09

Table 1. Comparison of system design labour costs – 2005 vs. 2010. Data sourced from REC Solar's analysis of system installation costs of approximately 5,000 residential systems.

Figure 1. Solmetric's SunEye 210 is an integrated shade analysis tool for solar site assessment.

	2005 hours/kW	$/Watt	2010 hours/kW	$/Watt
Warehouse pickup	1.50	0.05	0.50	0.02
Travel	3.00	0.11	3.00	0.11
Layout on site	0.89	0.02	0.44	0.01
Racking installation	6.67	0.17	4.44	0.11
Module installation	4.44	0.11	3.33	0.08
Electrical installation	3.33	0.16	2.22	0.10
Clean-up	0.44	0.01	0.44	0.01
Parts house runs	0.33	0.02	0.33	0.02
Testing of PV system	0.22	0.01	0.22	0.01
Close out Documentation	0.33	0.02	0.33	0.02
Total	21.17	0.67	15.28	0.49

Table 2. Comparison of installation labour costs – 2005 vs. 2010. Data sourced from REC Solar's analysis of system installation costs of approximately 5,000 residential systems.

Figure 3. Specialized module lift mechanism.

tools (see Fig. 1) and online system configuration tools such as the REC Solar Widget, which allows customers to size their own PV system online and see both the layout on a satellite image overlay and the related economic benefits. By understanding site conditions and basic system design parameters prior to performing a physical site visit, all site investigations can be performed in an expeditious manner allowing for focus on key design constraints.

The second critical improvement has been realized by many system integrators in their use of design tools. Templates and standard system designs have resulted in residential systems without custom engineering, while the myriad publicly available design programs and some proprietary solutions allow the designer to input basic system parameters to create an automated code-compliant system design. These tools have not only increased the speed of design but reduced the cost of labour as many integrators use these tools to radically shift their focus from engineering to configuration.

Installation labour and racking

The highest cost component of a residential PV system – besides the modules themselves – is the installation labour. Residential installation is an exceedingly labour-intensive process with very few revolutionizing opportunities to increase efficiency. That being said, there have been many small changes in the construction labour process that have allowed for continuous cost improvements (see Table 2).

Primary drivers in cost reduction include racking systems, tools, management of non-value added tasks, standardized training processes, and a larger workforce of skilled PV installers. The future will likely see further reductions in the areas of electrical installation, system prefabrication and improved technologies.

Racking system design changes over the past five years have had a tremendous impact on the shift toward an overall 'system design' perspective (see example in Fig. 2). The system design perspective views the project as a whole rather than as a series of individual components to be left to an installer for assembly. This shift focuses on identifying and eliminating redundant requirements and inefficiencies, and albeit a low-tech component, racking has been a key driver in increasing installation efficiencies.

For example, many racking systems have moved toward utilizing a single driver for all bolts, eliminating the requirement of having multiple tools. Innovations have been developed in the areas of snap-in components, pre-assembled components, and a general reduction in parts count. What was once a construction process on the roof including drilling and cutting of rails has become an assembly process. Component

Figure 2. The SnapNrack Clamp Assembly, an example of the 'system design perspective.'

assemblies are being established in warehouses by less skilled, lower-cost workers and delivered directly to construction workers for reduced field assembly time and cost. The system design approach and shift towards field or warehouse assembly rather than field fabrication has greatly reduced time spent on the roof.

Newly introduced tools and equipment provide incremental improvements in installation labour efficiencies such as installation trucks and module lifts customized for effective solar installation, such as that shown in Fig. 3. The module lift can prevent installers from transporting modules one at a time up ladders, allowing for more time to be spent on installing rather than transporting.

Customized trucks have greatly improved installation efficiencies. By having a vehicle with all necessary materials, tools and equipment, the installation team spends less time in parts houses picking up material and more time on the project. Less time is also spent loading and unloading the truck when properly sized and configured to accept ladders, pallets, conduit and other equipment.

As volume has increased over the past few years, many integrators have developed internal processes to focus on optimizing installation. Getting installers out of the warehouse and into the field takes an effective back-end support and training function. Using vendor-managed inventory systems helps reduce the possibility of running out of material on site, a situation that has traditionally forced construction crews to waste valuable time driving to and from part supply houses. Standardized approaches to field labour optimization have become an integral part of the residential integrator's success. By shifting crew sizes between different projects, efficiency can be greatly maximized.

It should also be noted that system integrators have become increasingly aware of safety issues as they have grown. In this light, module lifts have not only increased efficiency but also provided improved safety when it comes to transporting modules to the roof surface, especially for higher structures and steeper roofs. Needless to say, accidents drive up costs significantly in terms of insurance rates and lost time and can lower employee and management morale. Technical and safety training programs are therefore critical to keeping productivity levels up and costs down.

Balance of system components

System component advancement has been another key contributor to recent cost reductions. Aside from improved racking systems, there have been major improvements in system grounding and inverter design. Ground clips are now designed to be assembled into module clamps, electrically grounding modules to rails and thereby reducing labour time running long lengths of bare copper wire. These advancements in acceptable system grounding have brought simplicity to installation and reduced equipment requirements.

Some inverter design changes now include integrated disconnects eliminating the need to install a separate component (see inverter examples in Fig. 4). Many inverters are designed with two sections that are separable; one section contains all the electronic components, while the other contains the system wiring. When in previous years the whole inverter had to be removed and replaced in the event of failure, this was timely because the wiring had to be left in an electrically safe condition. Now, inverters can simply be unplugged and removed for shipment to manufacturers for repair or replacement.

Figure 4. Multi-section inverters with integrated disconnects (left: SMA America; right: Fronius USA).

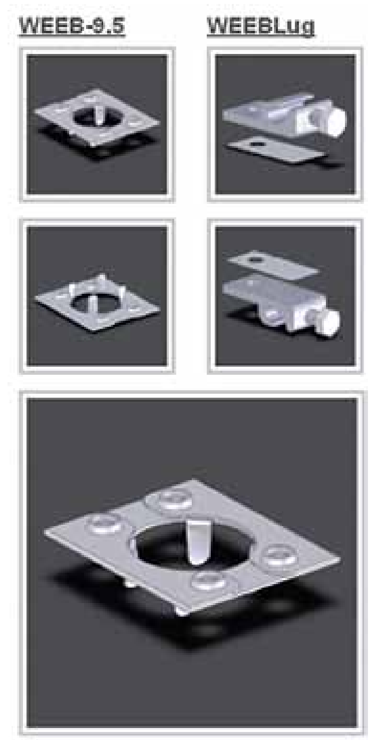

Figure 5. Example WEEB used to bond solar modules to solar mounts.

Source: Wiley

Module packaging is another important advancement creating considerable savings in material handling time and waste disposal. Several years ago, most module manufactures utilized cardboard boxes as a form of packaging. Cardboard increased the installation time for unpacking modules, materials handling and disposal. New plastic-corner clips allow for negligible material disposal and far lower time spent on handling materials.

Conclusions and outlook

As the PV industry continues to mature in the U.S., there will continue to be opportunities for streamlining the integration business. System costs would not be at the levels they are today and we would not have the thriving residential solar market we do were it not for the laser-focused effort on reducing system costs with respect to engineering, labour and components. From 2005 to today, the total cost for system design and installation has come down by 34% from US$0.88/watt to US$0.58/watt. This has been achieved by making only minimal changes to the module architecture. Improving module design by creating, for example, true plug-and-play solutions for system monitoring independent of specific modules or inverters will have a tremendous impact on total costs. Combined with continued innovation in installation and engineering efficiencies, the total cost reductions required to maintain a healthy residential market in the U.S. should be achievable despite the rapid decline of rebates.

About the Authors

Angiolo Laviziano is the CEO of REC Solar and has over 10 years' experience in the global solar market. He joined REC Solar in 2005, prior to which he was one of the founding members at Conergy AG and worked as CFO and Chief Sales Officer. Before that he worked at an investment bank in Hong Kong and at the Prime Minister's Office of Laos. Angiolo has presented several papers in the PV field, and has a Master's degree in business from the Koblenz School of Corporate Management in Germany and a Ph.D. degree in financial economics from the University of Hong Kong.

As VP of Construction Engineering and Design at REC Solar, **Ethan Miller** oversees the implementation of all solar projects, including branch operations, engineering, installation and service, as well as driving the company's expansion and product development. Since 2001, he has managed the engineering and installation of all REC Solar projects, and has a certification from the North American Board of Certified Energy Practitioners (NABCEP). He has a B.S. in mechanical engineering with a focus in renewable energy from California Polytechnic State University.

Enquiries

Tel: +1 805 709 2768
Email: p.kerans@mainstreamenergy.com