Low Weight, Low Cost Commercial-Scale Photovoltaic Inverter

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ABSTRACT

Photovoltaic (PV) module costs have dropped significantly in the past few years, while only modest cost reductions have been realized in Balance-of-Systems (BOS) costs, which includes both non-module hardware costs and installation costs. The industry is recognizing that installed PV system costs, once dominated by PV modules costs, will be increasingly dominated by BOS costs[1]. One approach to reduce BOS costs is to simplify installation and standardize system designs. This is particularly required in commercial-scale PV installations, the largest market segment, due to installation challenges with large existing buildings. Ideal Power Converters is developing a low weight, low cost commercial-scale PV inverter that can offer system designers and installers a new solution to simplify installation and lower BOS costs in an increasingly price sensitive market.

Keywords: inverter, photovoltaic, commercial

1 INTRODUCTION

The PV market is segmented into three market segments - Residential, Commerical, and Utility-scale systems. The medium-sized commercial-scale segment is the largest in both the US and worldwide. The US commercial-scale PV market segment installed 372MW in 2010 growing 72% over the prior year, and representing 42% of all US installations[2].

A Department of Energy survey for commercial-scale installations in 4Q 2010[3] showed that $2.54/W or 55% of the installed system costs for a commercial-scale PV system are BOS costs as shown in Figure 1. There is a need to futher reduce the non-module hardware costs such as inverters, but the greatest BOS cost reduction opportunity may be to reduce the installation costs. This can best be achieved by simplifying installation. (The study showed installation costs of $1.30/W which combines hardware markup, direct labor, overhead & profit.)

Commercial-scale PV installations are typically located on flat rooftops of large buildings such as businesses, schools, and government buildings. The PV module industry is developing solutions optimized for the specific needs of the commercial rooftop segment. Traditional balast weighted, tilted arrays may be replaced with flat rooftop solutions that eliminate roof penetrations, reduce roof loading and lower wind shear. Commercial rooftops PV modules may evolve toward solutions such as flexible thin film PV materials that roll out are integrated into traditional roofing products.

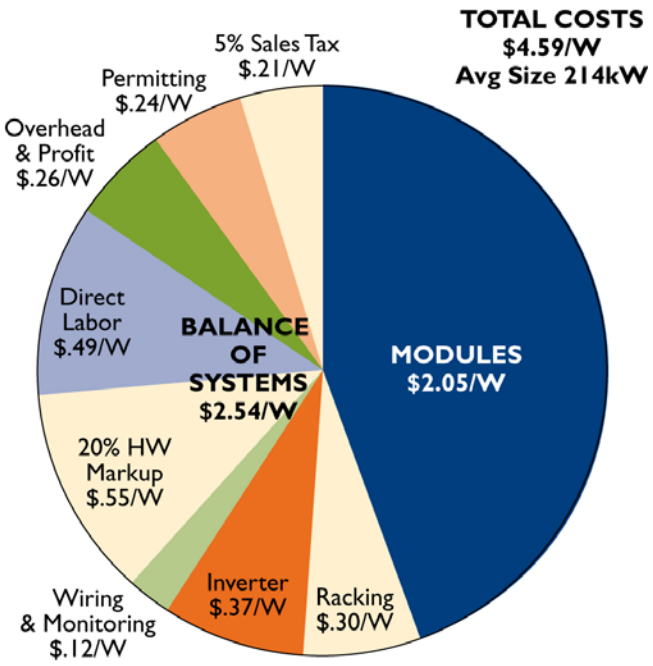

Figure 1. 4Q 2010 Average Installed Costs for US Commercial-Scale PV Installations[3]

As the commercial rooftop market segment continues to rapidly grow and mature, similar optimization is required for inverter systems. Commercial-scale PV systems are normally a distributed generation solution that provides daytime energy directly into the building system main panel board. As result, these systems need to deliver standard commercial power – 480VAC 60Hz 3-phase in the United States.

Existing 480VAC 3-phase commercial-scale PV inverter solutions available in the US are excessively heavy and difficult to ship and install. Ideal Power Converters (IPC) has developed and patented a new power converter topology that reduces the weight and size of commercial-scale PV inverters by greater 90 percent while using standard grounded PV arrays. This new inverter

technology lowers cost of materials, manufacturing, shipping and installation. Additionally the IPC inverter will further improve Levelized Cost of Energy (LCOE) with improved efficiency and higher reliability than with convential voltage-source converters.

IPC's initial product is a 30kW 480VAC commercial-scale PV inverter for the US market. IPC has successfully installed and operated a prototype PV inverter using its patented current-modulation topology. Figure 2 shows the pilot installation and a comparison to a conventional PV inverter. The conventional PV inverter shown in the photo is 20 years old. However new best-in-class (30kW 480VAC) PV inverters are as large and heavy as this old unit illustating that the industry has not significantly improved in size or weight of these products in twenty years.

Figure 2. PV Inverter Pilot Installation

2 MAGNETIC METAL REDUCTION

In conventional PV inverter systems, the magnetic components including transformers, reactors and chokes are the largest, heaviest and most expensive part of the inverter. These components are constructed of magnetic metal materials including copper wire and magnetic steel. It is not possible to cost reduce these commodity metal materials, so therefore to significantly reduce PV inverter material costs, the amount or weight of these magnetic metal materials must be reduced.

IPC's new current-modulation PV inverter technology reduces the system weight of PV inverters by greater 90 percent compared to conventional systems as shown in Figure 3. The system weight reduction is due to approximately a 95 percent reduction in magnetic metal materials used, primarily copper wire and magnetic steel used in transformers and inductors. This significantly lowers the materials and manufacturing cost of the inverter.

In addition to lower costs, the reduced magnetic metal content has important sustainability benefits:

- There is lower embodied energy in the IPC inverter, as magnetic metals have high energy costs from the mining and processing.
- Metal mining and processing is polluting. The environmental externalities are directly related to the amount of metal required, so that IPC's product will reduce pollution generated from metal supply chain by about 95 percent.
- The IPC inverter technology reduces the amount of limited metal ore resources required from the earth. The reduction in copper material is particularly important, as the cost of this commodity is near record highs. The IPC inverter uses about 2 lbs of copper while competing systems uses about 100 lbs. As the number of power converters for solar, as well as other applications continue to grow dramatically in coming decades, IPC's products will reduce pressure on limited copper ore deposits.

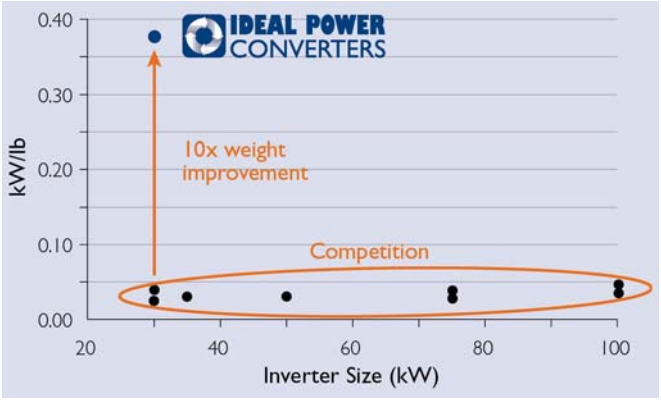

Figure 3. Power/Weight Comparison

3 SHIPPING & INSTALLATION COST

In addition to lower materials and manufacturing cost for the IPC inverter, the smaller size and lower weight, reduces indirect costs of shipping and installation. The shipping and installation can be as high as 50% the inverter price with commerical-scale inverter systems. Figure 4

shows that these costs can be reduced by 85-95% with IPC's low weight inverter system.

The IPC inverter will ship UPS ground, while a heavy conventional inverter requires special freight truck delivery. IPC's inverter will be manufactured in the US, while most competing products are manufactured primarily in China due to lower costs of magnetic metal materials available there, and then shipped half-way around the globe.

The IPC inverter can be installed by two installers on a wall in about an hour without special equipment. A conventional inverter of this power level and voltage requires a poured concrete pad. After drying for several days, a forklift or crane is required for mounting the inverter on the cured concrete pad. Most commercial PV installation companies, must subcontact forklift or crane equipment rental with operators adding significant cost and logistic coordination.

IPC's inverter solution further reduces the embodied energy as no specialized heavy equipment is needed to ship or install the system.

	IPC 30kW	Conventional 30kW
Shipping	UPS Ground $50	commercial freight $500–1,000
Mounting	wall-mount 2 installers for 1 hour $250	poured concrete pad forklift/crane rental $1,500–5,000
Indirect Costs	$300 $0.01/Wp	$2,000–6,000 $0.07–0.20/Wp

Figure 4. Shipping and Installation Cost Comparison

Conventional commercial-scale PV inverters are generally mounted on the ground at the building's exterior due to their large size and weight. The small, light weight IPC inverter also gives the system designer and installer more design flexibility such as mounting the inverter inside the building utility room or high on a shaded exterior wall. These installation options allow the optimium inverter location to utilized to lower wiring costs, wiring losses, reduce theft/vandalism, and other benefits.

4 INVERTER EFFICIENCY

The economic payback of PV systems drives their adoption. Even modest improvements in efficiency strongly impact the overall system economic payback. The IPC inverter directly delivers US commercial standard power – 480VAC 3-phase with maximum efficiency. Figure 5 provides a California Energy Efficiency (CEC) weighted efficicency comparison of the IPC inverter with other 480VAC commercial-scale inverters.

The IPC inverter delivers one to two percent higher efficiency than competing products. The energy losses related to the inverter are also reduced by about one third.

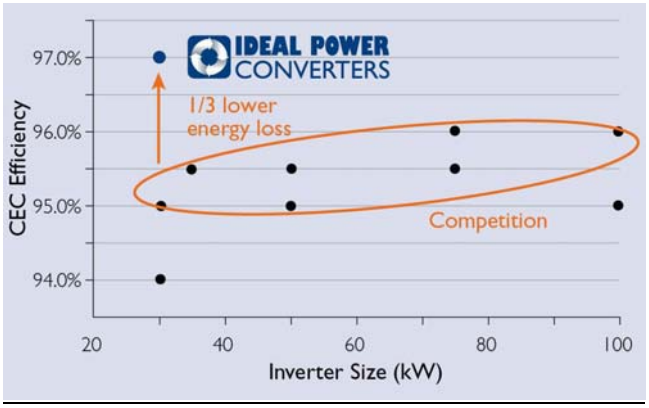

Figure 5. Efficiency Comparison

5 MAINTENANCE COST

IPC inverter is designed for improved inverter reliability and reduced Operations & Maintenance costs.

PV inverter reliability is the leading cause for PV system failure, and the leading cause of PV inverter failure is failing electrolytic capacitor components. Industry studies have shown that electrolytic capacitors age, fatigue and fail[5]. Sometimes they fail catastrophically, as with a recent recall from a major PV inverter manufacturer where the steel door of its inverters were blown off from exploding electrolytic capacitors[6]. In spite of this, most manufacturers continue to depend on electrolytic capacitors for their products. IPC has eliminated all electrolytic capacitors from its products, and only uses more reliable and expensive thin film capacitors.

IPC has taken other steps to improve reliability. The inverter uses extremely soft switching on its semiconductor switch components, which lowers both electrical and thermal stresses on these devices. This leads to longer trouble-free operation. IPC products have higher over-voltage tolerance to incidents such as lightning strikes, which is another leading cause of failure.

Operations & Maintenance Costs are further reduced with the IPC inverter. No air filters are required, eliminating a regular maintenance cost of replacing these.

In the rare case of an inverter failure, a new unit can be shipped UPS ground in 2-3 days, and installed in only a 30 minutes with two installers. Conventional commercial-scale inverters may require 4-6 weeks to replace if damaged, and the difficulty of installation is duplicated for shipping a replacement inverter and returning the damaged unit to the manufacturer. IPC's replacement process also simplifies return of old units, which will be repaired or recycled for materials.

6 SCALBILITY

The IPC inverter is more manufacturable due to the smaller size and lighter weight. It also uses only commodity components and materials eliminating many potential bottlenecks to producing the unit in high volume. IPC will use US manufacturing subcontractors to assemble its products, creating important US clean tech manufacturing employment.

The 30kW PV inverter is the first commercial product utilizing IPC's patented current-modulation topology, but this technology will be applied to many other applications, including utility-scale PV inverters, wind turbine converters, grid storage battery inverters, high power AC motor control, and hybrid-electric vehicles.

IPC has also licensed its technology to Lockheed Martin for certain government and vehicle applications. IPC is co-developing with Lockhed Martin an Intelligent Microgrid Solutions for military Forward Operating Bases that can reduce diesel fuel requirements by up to 40%.

7 CONCLUSION

IPC's 30kW PV inverter lowers the cost of materials, manufacturing, shipping and installation for commercial-scale PV inverters, while simulatenously improving efficiency and reliability. The inverter will be particularly attractive for large flat rooftop systems such as on businesses, schools and government buildings by dramatically reducing the inverter installation costs and providing more flexibility on the installation location. IPC is currently completing development of its initial product including required industry certifications.

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