IDEAL POWER CONVERTERS

Low Weight, Low Cost, High Efficiency Commercial-Scale Photovoltaic Inverter

Successful test proves new inverter technology with >90% weight reduction

During the past three years the cost of polysilicon, the principle material for most PV modules, has plummeted by 85%, leading to a 50% decline in the cost of PV modules. In comparison, the cost of copper, one of the principle materials for conventional PV inverters, is near record highs, and PV inverters have seen little price reduction. Cost reduction rates for PV systems will slow as Balance of System costs (including the PV inverter) begin to dominate total installation price[1]. Significant inverter and BOS cost reductions are necessary for PV systems to reach widespread grid-parity with fossil fuels, but the consensus from conventional PV inverter manufacturers indicate that inverters are unlikely to achieve significant cost reductions due to their extensive use of expensive raw materials[2].

Magnetic components, including transformers, reactors, and inductors are the largest, heaviest and the most expensive components of inverters[3]. These components are built primarily of copper and magnetic iron. Since it is not possible for the PV inverter industry to reduce the cost of these commodities, the only way to achieve a significant cost reduction in PV inverters is to reduce the amount or weight of magnetic-metal materials used.

> *"IPC's current-modulation electronic power converter topology improves cost, efficiency, and reliability. It is one of the most significant advances in power electronics in decades, which is critically required for the clean-energy industry."*
>
> —Dr. Hamid A. Toliyat, Professor and Director of Electric Machines & Power Electronics Lab, Texas A&M University

IDEAL POWER CONVERTERS (IPC) has developed a power converter topology that reduces inverter weight by more than 90%, lowering the cost of manufacturing, shipping and installation. IPC was granted two basic US patents on its power converter topology, and has several additional US and international patents pending. "IPC's current-modulation electronic power converter topology improves cost, efficiency, and reliability. It is one of the most significant advances in power electronics in decades, which is critically required for the clean-energy industry," said Dr. Hamid A. Toliyat, Professor and Director of Electric Machines & Power Electronics Lab at Texas A&M University.

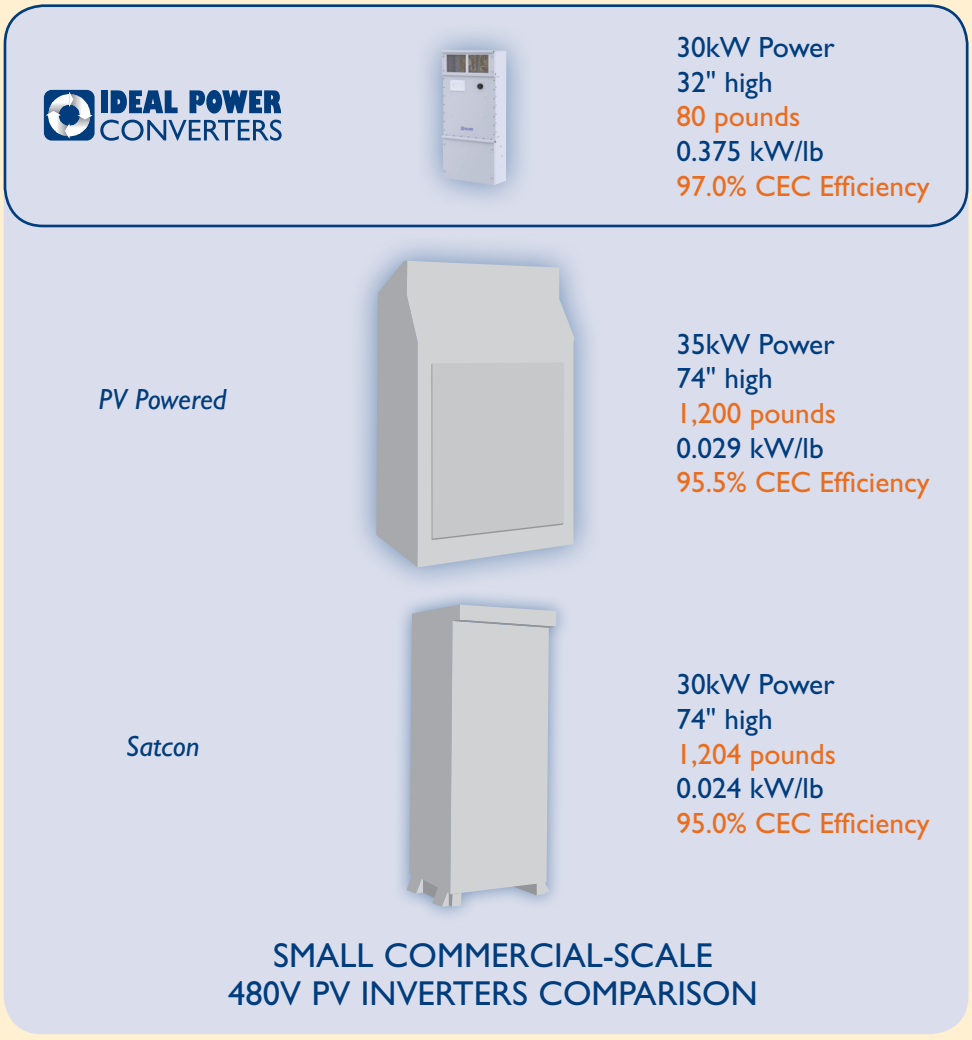
IPC has successfully tested a prototype of its initial 30kW PV inverter at the Austin Convention Center in cooperation with Austin Energy. The pilot conclusively proves that IPC's topology reduces the weight of a conventional PV inverter by more than 90% while using only commodity materials and components. This weight reduction leads to lower direct inverter cost (price), and lower indirect inverter cost (shipping & installation). Lower LCOE (Levelized Cost of Electricity) is further improved by the superior efficiency and reliability of IPC's PV inverter topology.

IDEAL POWER CONVERTERS

Commercialized IPC Inverter

IPC is developing its initial 30kW PV inverter and is supported by the State of Texas Emerging Technology Fund, and Battery Ventures. This breakthrough inverter is ideal for large, flat-rooftop arrays on commercial buildings such as warehouses, retailers, schools and government buildings.

The dramatically smaller size and lower weight of the IPC prototype inverter is proven in this pilot project. The conventional inverter shown in the photo is twenty years old, but it is similar in size and weight to current best-in-class (30kW 480VAC 3-phase) inverters. This also illustrates that conventional PV inverters have made little progress in twenty years in reducing their size and weight.



SMALL COMMERCIAL-SCALE
480V PV INVERTERS COMPARISON

Voltage-source inverters are the dominant power converter topology used in photovoltaic inverters. IPC uses a completely new approach called current-modulation

Improving U.S. Army Sustainability

Ideal Power Converters has licensed its technology to Lockheed Martin for government, vehicle and certain transportable applications. Lockheed Martin will use IPC's converters to create more efficient and versatile Intelligent Microgrid Solutions and improve performance of electric/hybrid-electric vehicles, among other applications.

Lockheed Martin received a contract from the US Army to develop a Hybrid Intelligent Power (HI Power) microgrid system. HI Power will reduce energy consumption and fossil fuel usage at military field bases by as much as 40% over current systems. A key component of the HI Power program is the ability to smartly distribute power from generators to outlets and throughout the power grid. Supplied by Ideal Power Converters, Inc., the HI Power converters eliminate the possibility of a single point of failure by managing power at multiple points in the microgrid in addition to the central controller.

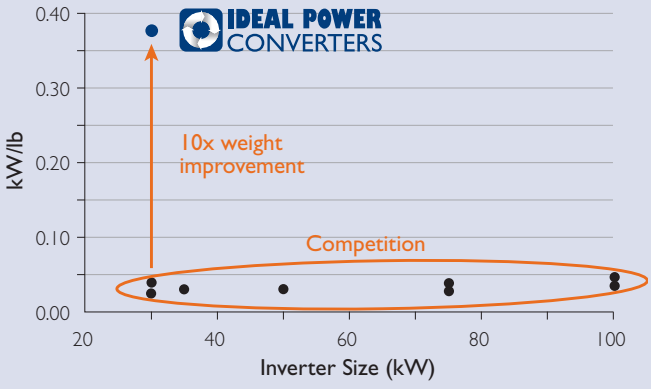
"Intelligent microgrids reduce the volume and weight of deployable base camps, resulting in a reduction in transportation and operating costs, as well as a 40% decrease in fuel consumption," said Gil Metzger, director of Force Projection and Power Management Systems at Lockheed Martin Missiles and Fire Control. "By efficiently and dependably supplying power to tactical operations, fewer Soldiers are placed in harm's way during the transportation and daily operation of the base."

topology. IPC's topology uses similar components and materials as the voltage-source inverters, but operates in a completely unique and patented method.

The **major benefits** of the IPC patented topology include:

- **Reduced magnetic-metal weight and cost.** This is achieved by eliminating the transformer while providing isolation for grounded PV arrays and reducing inductive filter requirements.
    - The magnetic-metal weight in IPC's 30kW PV inverter is 25lbs, while conventional inverters with similar capability have about 600lbs of magnetic-metal. The IPC inverter uses 4lbs of copper compared to about 100lbs in conventional systems.
- **Higher efficiency** and wider DC-voltage-operating range than voltage-source inverters, maximizing energy harvesting.
- **Higher reliability** since no electrolytic capacitors are used in IPC's inverter. This completely eliminates the components most likely to fail in PV inverter systems, leading to much longer inverter product life and reduced maintenance costs.

The power/weight ratio of the IPC 30kW PV inverter compared to other 480V 3-phase commercial-scale (30–100kW) PV inverters for the US market is illustrated below.



COMMERCIAL-SCALE 480V INVERTER POWER/WEIGHT COMPARISON

Lower Materials and Manufacturing Costs

Even with its dramatic reduction in weight, the IPC 30kW PV inverter only uses commodity materials and components directly reducing the cost of materials and manufacturing. The cost and performance improvements in IPC's products will disrupt the worldwide PV inverter market and have the potential to transform the inverter industry by allowing the United States to become a worldwide leader in manufacturing for both domestic and export markets.

In 2009 only 3% of the worldwide manufacturing of PV inverters occurred in the US and 65% of US domestic PV inverter needs were imported primarily from China and Europe[4]. In 2010 the worldwide PV market doubled to $5 billion dollars, and leading US-based PV inverter suppliers further migrated their manufacturing to China primarily to lower their magnetic-metal costs, which are dominated by Chinese firms.

Due to its dramatically lower use of magnetic-metals, IPC's technology and products can alter this trend and create significant US manufacturing employment and exports. IPC is seeking government support opportunities at the national, state and local levels to assist in creating this industry transformation. IPC's goal is to make the United States the technology and manufacturing leader in clean energy power electronics, not only for PV inverters, but also converters for energy storage, wind turbines, and high efficiency AC motor drives.

Lower Shipping and Installation Costs

The large weight reduction in the IPC inverter also dramatically reduces shipping and installation costs, which are not normally considered in the direct cost of the PV inverter. IPC's 30kW inverter weighs only 80lbs and will be shipped by UPS ground. Competing systems require commercial freight shipment with an order of magnitude higher shipping costs.

The installation of IPC's inverter is also less expensive. It is a wall-mount system that can be installed by two technicians without special equipment. Competing systems require a custom poured concrete pad prior to installation. A

crane or forklift is also required for mounting the heavy inverter system. Most PV installation firms lack this type of equipment, which requires a third party subcontractor just to move the inverter. In addition, the small size and light weight of the IPC inverter provides more flexibility in mounting locations, such as rooftops or building interiors, while conventional systems need to be located outside at the foot of the building.

SHIPPING AND INSTALLATION COST COMPARISON

	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

Higher Efficiency

The IPC prototype inverter system installed in the pilot has been tested for grid safety and efficiency by Intertek, North America's largest independent PV-inverter testing laboratory. These tests are a subset of the North American industry certifications to be completed in the spring of 2011, and further prove the capabilities of IPC's topology. (Intertek test reports are available on request.)

The efficiency tests performed by Intertek prove that the IPC prototype inverter has better efficiency than best-in-class PV inverters. Following the prototype tests, several efficiency optimizations are being implemented in IPC's production inverter that will enable it to provide 96.5–97.0% CEC efficiency, which is superior to any other North American commercial-scale (25kW–100kW) inverter delivering 480V 3-phase commercial power.

Improved Reliability

An additional benefit of IPC's topology is superior reliability. IPC's topology improves reliability through inherent design improvements such as elimination of all electrolytic capacitors, reduced switch stresses, redundant cooling fans and increased robustness to overvoltage transients.

Electrolytic capacitors, which fatigue and fail over time, are used in most PV inverters and are the principle cause of PV-inverter and PV-system failures[5]. They also affect PV-system yield due to higher maintenance costs and system downtime. IPC inverters use no electrolytic capacitors, resulting in longer operating life.

IPC inverters have 100% soft switching for both turn-on and turn-off. This reduces switching losses, electrical stresses and operating temperatures on the switches and other components, leading to longer operating life.

The IPC inverter is more robust to voltage surges than conventional voltage-source inverters, providing increased protection from lightning and DC overvoltage.

System reliability is further improved on larger commercial systems. These might normally use a 100kW inverter, but using several IPC 30kW inverters avoids interrupting the entire system during inverter maintenance. Additionally, the IPC inverter replacement process can be completed in only a few minutes.

Conclusion

IPC's successful pilot test proves that its patented current-modulation power converter technology reduces the weight of commercial-scale PV inverters by more than 90%. The IPC inverter will improve the direct cost, indirect cost, efficiency and reliability of commercial-scale PV systems. IPC technology can enable the US to become a global leader in manufacturing these products for both domestic and export markets. The IPC breakthrough technology is also applicable to other clean energy infrastructure markets, including microgrids, utility-scale PV inverters, grid storage, wind converters and AC motor drives.

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