

“INNOVATIVE HIGH-PERFORMANCE CONCENTRATOR PV SYSTEM FOR GRID-CONNECTED APPLICATIONS”

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A highly modular (5 kw — 25 kw) cost-effective Fresnel lens high-concentration PV system is now available for immediate deployment. This state-of-the-art system represents the first technology for large-scale multi-megawatt use of high-concentration PV in the world. The system is based on an innovative integrated structure called a MegaModule™ that combines the structural components for aligning the Fresnel lens with the concentration solar cell in a highly cost-effective manner. The system has completed large-scale field-testing in severe geoclimate zones and is optimized for long-term 20-year reliability and low maintenance. The heart of the system is a high-performance back-contact high-concentration solar cell that has established world records for sunlight-to-electricity energy conversion efficiency combined with volume production. High-concentration PV directly attacks the principle cost-driver of most PV systems, the solar cell, by significantly (250X – 400X) reducing the amount of solar cell material needed to generate electricity. The MegaModule™ system also offers significant potential for in-country manufacturing.

KEYWORDS: GRID-CONNECTED, LARGE, UTILITY-SCALE, FRESNEL, MEGAMODULE, HIGH-CONCENTRATION, CONCENTRATOR

Amonix, Inc. of Torrance, California has completed development of an innovative highly modular, high-performance photovoltaic system based on its patented high-concentration technology for large-scale, multi-megawatt installations around the world.

BACKGROUND — “Why Concentrator?” — Cost effectiveness is a critical factor for mainstream acceptance of solar energy generation. For the cost-driven terrestrial markets, the industry's design focus has been to reduce the principal cost “culprit” of the PV system: the silicon solar cell. All approaches strive to reduce the solar cell material content. One trend in the PV industry is to pursue low cost by reducing the material thickness (thin-film amorphous silicon). Other approaches include development of alternate thin-film solar cells using ‘exotic’ materials.

Amonix pursued a highly cost-effective approach by reducing the area of costly cell material required to generate a given amount of electricity. Using a low-cost intermediary Fresnel lens to focus and concentrate sunlight onto a specially designed, high-performance small area solar cell (1 cm²), we have been successful in reducing the required silicon cell area by over 250 times with our Integrated High-Concentration Photovoltaic (IHCPV) system design.

Although the high-concentration photovoltaic concept had been theoretically studied for many years, it was not considered commercially practical because of the lack of a solar cell capable of withstanding the environment generated by highly concentrated sunlight. Amonix was able to successfully bring its extensive semiconductor technical background to bear on the key element of the IHCPV system - the solar cell.

Key features of the high-concentration technology include:

- High performance, concentration photovoltaic silicon solar cells that received the 'R&D 100 Award' for technical achievement.
 - This solar cell is the 'heart' of our IHCPV system and contributes to the very high total system AC efficiency of 16% plus
 - Concentrating PV technologies directly attack the principal cost driver of any PV system — the costly solar cell — by reducing the amount of solar cell material required to generate a given amount of electricity by a factor equal to the concentration ratio — in our case, 250 times less solar cell material required
 - This inherent cost reduction factor translates into tremendous potential for cost reduction at multi-megawatt levels of production. The system is already very cost competitive at modest levels of production; projections to 25 — 50 megawatts indicate a significant advantage over competing technologies
- Integrated High-Concentration PV (IHCPV) receiver plate producing 110+ watts_{AC} at rated concentration (PVUSA). Each MegaModule™ houses 48 of these receiver plates and produces 5 kilowatts.
- Highly modular Fresnel lens integrated modules (MegaModule™) operating at approximately 250X concentration.
- A new patented hydraulic tracking drive with custom tracking controller capable of handling large arrays in winds up to 100 miles per hour. When the system detects winds exceeding 45 miles per hour, the system is programmed to drive itself into safety stow.

With its built-in tracking, the system's energy production factor is significantly higher than that of fixed flat-plate PV systems. This advanced system is the culmination of over six years of 'hands-on' field-testing and product refinement in severe geoclimate zones such as the desert areas of the Southwestern United States. In partnership with several of the nation's largest utility providers, 100 kW of grid-connected evaluation and demonstration systems were deployed in five different geoclimate zones for long-term (four year) performance evaluation. All of the 'lessons learned' from these test installations were incorporated into the new, patented MegaModule™ system configuration (Figure 1). The Company has begun full-scale production of commercial MegaModule™ systems with plans to produce greater than one megawatt next year.

Each array produces 5 kilowatts_{DC} per MegaModule™ at PVUSA test conditions¹ (the preferred commercial rating for utility scale systems). Configurations are flexible from 5 kilowatts (1 MegaModule™) to 25 kilowatts (5 MegaModules™) depending on customer requirements.

Proprietary software, especially developed for the IHCPV system, is used in order to ensure the most efficient utilization of land and the solar resource. This software optimizes the physical layout of a particular site location for such factors as size, shape, elevation and shading. This software, coupled with Amonix's field experience, helps to assure the maximum potential of each installation.



Figure 1: A four MegaModule™ System produces 20,000 watts

Each aspect of the system has been matched to meet the requirements of large-scale, grid-connected customers.

- All 48-receiver plates in each MegaModule are electrically combined in-series to generate as high a voltage as possible per MegaModule. This high voltage allows the use of higher efficiency inverters used to convert the DC power generated by the IHCPV system into AC for grid connection.

¹ PVUSA Test Conditions for Concentrator Systems — 850 watts per square meter DNI, 25⁰ C ambient temperature, 3 meters per second wind speed

- All components are designed for 20+ year life in harsh geographic locations. The entire system has been subjected to rigorous field-testing and evaluation to ensure trouble-free operation.
- Because of its optimized thermal coefficient, the IHCPV system can be passively cooled, that is it needs no external source for cooling such as water. This is especially significant for remote, desert installations where water cooling represents a life-cycle risk.
- The standalone computer based tracking system has the capability to interface with line or wireless modem to allow remote control of a large field of IHCPV systems from a central base. In addition, instantaneous data such as temperature, power output, and solar resources can be remotely monitored.



General field layout and installation of tracking drive



Lift and mounting of MegaModules™



Part of an array field — note the two MegaModule system (10 kilowatt) in the foreground — the MegaModule configuration allows maximum flexibility in field layout

An important aspect of the system design is high percentage of system components which can be manufactured 'in-country' or onsite. Great care was given to industry standard fabrication methods and techniques. This feature allows important strategic and cooperative partnerships with countries eager to pursue renewable sources while simultaneously invigorating local infrastructures. The solar cell, because of its efficiency and use in a concentrating system, represents less than 10% of the total system content. The 90% balance, or any percentage is capable of being manufactured in country.

In summary, Amonix has developed and field proven a cost-effective, innovative, high performance, high-concentration photovoltaic system for large-scale grid-connected applications.

Amonix's recent 300 kilowatt installation, in cooperation with a major domestic utility partner, represents the largest deployment of high-concentration PV systems in the world. Future multi-megawatt installations are planned utilizing "fields" of IHCPV systems.