Delivering Grid-Parity Solar Electricity on Flat Commercial Rooftops

Brian Sager
Nanosolar, Inc., Palo Alto, CA

ABSTRACT

Nanosolar has developed a nanoparticulate printing process that permits the rapid and high-throughput roll-to-roll production of solar cells constructed on low-cost metal foil. The economics of the Nanosolar printing process provide a substantial reduction in cell cost. However, achieving grid-parity PV system economics using Nanosolar cell technology requires further design innovations at the module, mounting system, inverter, and system level. Each of these components will be optimized from the systems perspective to ultimately drive fully-installed system cost to grid-parity. The design of optimized components will be informed by a framework of real-world performance feedback

1. Objectives

Nanosolar has developed a new generation of solar electricity cell technology based on a printed semiconductor – which permits substantially improved cost efficiency. However, in order to translate this cell advance into grid-parity PV systems economics, the entire system and each of its components have to be similarly improved and optimally redesigned, allowing for a re-definition of the interfaces and component functions from a systems-optimized perspective. Nanosolar is leading a team to develop an optimized solar system for the key market of corporate customers with flat-roof commercial buildings (see Fig. 1 for a typical rooftop installation). The ultimate target for this system optimization project is to achieve grid-parity system economics for this market.

Our SAI team is focused on utilizing scalable PV cell technology with industry-best $/Watt performance to deliver grid-parity PV systems economics for large-scale commercial building installations. We will do so through the development of an integrated suite of system components and designs based on innovations in module, inverter, and mounting technology and informed by a framework of real-world performance feedback. Our team will bring together innovations in cell and module technology (Nanosolar), inverter technology and systems optimization (Conergy AG), and mounting technology (Sunlink LLC) to deliver a pilot installation (Suntechnics) with grid-parity customer economics.

2. Background

Several factors have slowed the deployment of PV systems onto commercial rooftops in the U.S. These factors include economics (high upfront cost), invasive installation practices, and volatile government subsidies, rebate programs and tax credits at both the state and federal levels.

Commercial building owners and facility managers require payback periods less than five years to justify their investments. System costs have historically been too high to permit compelling investment decisions; total installed system costs were as high as $\$7/W_p$, and, in the U.S., have often not been cents/kWh optimized. The current system cost translates into a payback period of more than 10 years (before subsidies) and still about 5.4 years even after substantial government subsidies, outside the range which building managers will typically accept.

System costs have been too high in part due to the cost of modules and in part due to relatively complex, custom, and labor-intensive installation practices. After the module, the greatest contributors to system cost are, in order of contribution, construction and system installation, the mounting system, and inverters.

Deployment practices have also impeded market growth. With invasive mounting infrastructures, rooftop penetrations decrease the roof lifetime while typically voiding warranties for the rooftop itself. Conventional solar modules are mounted onto racks that must be attached mechanically to the rooftop, requiring penetration into the roof to provide attachments strong enough to withstand potential wind load. Installation of a roof-attached system is labor-intensive, adding additional time and cost to the system installation process.

While leading to deployment volume, government incentives such as subsidies, rebates, and tax credits have not always been implemented with sufficient longer-term predictability to create a cohesive and investible market, and policy changes have made it difficult to rely on a particular incentive framework, especially for large commercial deployments carried out over time.

Fig. 1. PV installation on a flat commercial rooftop in California (using SunLink LLC's first generation of non-pervasive mounting system).

3. Technical Approach

3.1 Solar Cell Technology

Nanosolar has developed proprietary technology based on Copper-Indium-Gallium-diSelenide (CIGS) absorber technology that allows the printing of this semiconductor material using a high-speed, high-throughput roll-to-roll manufacturing process.

A central challenge in cost-effectively constructing a large-area CIGS-based solar cell or module is that the elements of the CIGS layer must be within a narrow stoichiometric ratio on nano-, meso-, and macroscopic length scale in all three dimensions in order for the resulting cell or module to be highly efficient. Achieving precise stoichiometric composition over relatively large substrate areas is however difficult using traditional vacuum-based deposition processes.

For example, it is difficult to uniformly deposit compounds and/or alloys containing more than one element by sputtering or evaporation. Both techniques rely on deposition approaches that are limited to line-of-sight and limited-area sources, tending to result in poor surface coverage. Line-of-sight trajectories and limited-area sources can result in non-uniform three-dimensional distribution of the elements in all three dimensions and/or poor film-thickness uniformity over large areas. These non-uniformities can occur over the nano-, meso-, and/or macroscopic scales. Such non-uniformity also alters the local stoichiometric ratios of the absorber layer, decreasing the potential power conversion efficiency of the complete cell or module.

Nanosolar overcomes these challenges by printing nanoparticulate CIGS precursor materials onto low-cost metal foil substrates, and performing a rapid thermal processing to convert the nanoparticulate coating into a CIGS absorber layer By locking in the appropriate stochiometry into the nanoparticulate precursor material, spatial uniformity is ensured in the coated layers, while printing at high speed and throughout minimizes solar cell cost.

3.2 Mounting System.

Optimal design of mounting structures for large flat roof PV arrays requires the balance of several opposing design constrains. Specifically, such mounting structures need to support the inclination of the module at near latitude tilt to provide maximum electrical output, be aerodynamic with regard to the wind so that the loads imposed on the structure by wind are minimal and minimal ballast or connections to the structure are necessary, and be relatively light weight so that the structure does not add significantly to the weight that the roof must bear.

In this project, we will design mechanical structure of modules together with the mounting system and the system reference design. We will identify the minimal application-specific structural requirements through wind-tunnel and other tests, and develop a novel low-cost kWh-optimal mounting and deployment system.

3.3 System Design.

We will develop a system reference design for flat commercial rooftops based on standardized system blocks with kWh-optimized performance, minimal site-specific engineering and permitting, and rapid deployability. Our approach is based on the definition of a "standard" system block within which we apply our product design and technology innovations, and streamline deployment with respect to the major application segment of large-area low-slope rooftops on commercial buildings.

3.4 Inverter Technology.

Our system block design is enabled through innovative plant-scale inverter technology under development by Conergy AG, which will be brought to commercial readiness as part of this project. We will tune the kWh-performance of the system tightly in particular at the module / inverter interface.

4. Significance

A successful outcome of the project will bridge the gap in bringing the promise of low-cost solar electricity to the market. A high-throughput roll-to-roll production of printed solar cells will allow the manufacturing of solar modules at a cost that ultimately permits the deployment of grid-parity solar systems — an unprecedented cost level that will provide a means for energy consumers to access far more economic and stable electricity pricing throughout the US and without dependence on foreign energy sources.