Integrated Concentrating (IC) Solar Façade System

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ABSTRACT

A concentrating photovoltaic (PV) system is being developed as a dynamic day-lighting system for box-window curtain wall assemblies in buildings. The IC system is composed of multiple concentrator modules that are situated within a glass façade or glass atrium roof of a building and are mounted on a highly accurate, inexpensive tracking mechanism. (See Figure 1.) The system capitalizes on the structural components, encasements and maintenance schedules of the existing façade systems and uses minimal and inexpensive materials. Many of the impediments previously facing the commercialization of concentrating systems are addressed by system integration into the substantial surface areas of large building structures that are not subject to wind and particulate loads or maintenance requirements of the stand-alone concentrators. The architectural integration of the IC system ensures an efficient transfer of electric and thermal energy into interior applications while reducing solar gain and enhancing day-lighting. Energy production projections show cost payback periods are substantially below those of existing solar systems.

1. Objectives

The research objectives of the system directly relate to several goals of the DOE Solar Energy Technologies Multi-Year Program Plan. In particular, the goal of the IC solar façade system is to maximize the utilization of solar energy to lower the overall energy consumption profile of buildings through the synergistic combination of power generation (using PV cells) and high quality heat capture with a simultaneous reduction in building cooling and lighting loads. By transferring concentrating technology to a day-lighting system within 'double-skin' façade systems, we propose a different model for day-lighting with a reduction in unwanted solar gain, whereby heat is removed from the building envelope before it is transmitted to the interior This approach has several advantages over existing day-lighting systems, which are unable to viably capture solar energy while providing diffuse daylight for interior spaces.

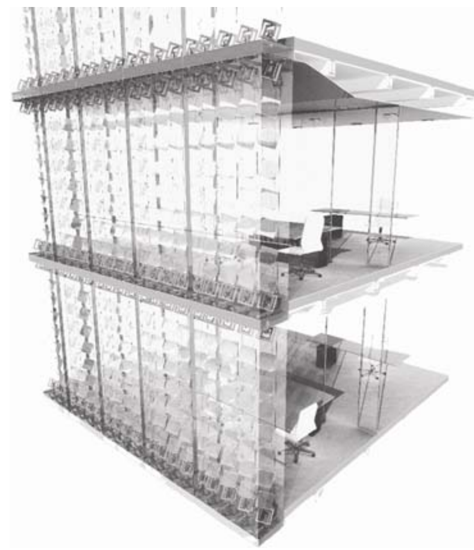

Figure 1. IC Solar Façade – Integration into Curtain Wall.

In Phase 1 of this project, we are designing, building, and extensively testing a full-scale panel installation of Version 4.1 of the IC Solar Façade system at the Syracuse Center for Excellence in Environmental and Energy Systems. (Figure 2) This demonstration follows the building and testing of three previous prototypes, including one that continues to be a test bed at Rensselaer for the evaluation of heat and power generation of multiple cell types within the IC Solar Module (Figure 3). The post-occupancy testing of full-scale prototypes at the Center for Excellence will be critical in assessing the operating constraints on power generation of the system, as well as the assessment and development of optimum applications for direct transfer to distributed building systems. For the latter challenge, we are currently collaborating with the Lighting Research Center at Rensselaer and Nextek Corporation to develop DC transfer systems to solid state lighting. We will collaborate with Syracuse University on the testing of this system and are currently negotiating with strategic industrial partners to help develop systems for using high quality heat in distributed absorption refrigeration cooling units.

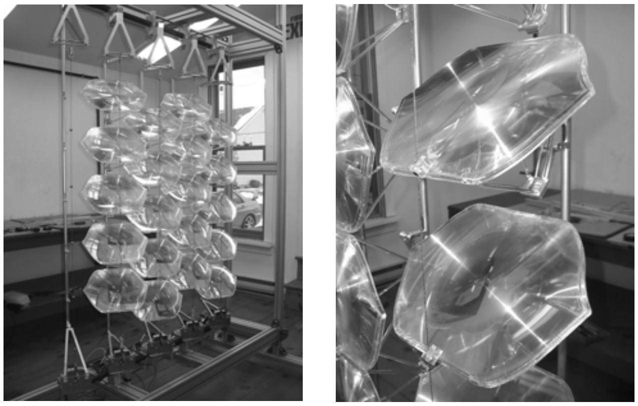

Figure 2. IC Solar Façade – Prototype Version 4.1

2. Technical Approach

The IC system is designed to effectively use the direct solar irradiance incident on the surface(s) of a building to augment or power the building. (Figure 1) This irradiance, after initial reflections at the air/glass/air interfaces on the exterior of the building, is transmitted to a faceted type lens. The lens directly concentrates (>400:1) the light onto a high-efficiency multijunction PV cell recently demonstrated at 39.4% under 411 suns. [1, 2] The power not converted to electricity is captured via a coolant flow through the receiver on which the cell is mounted. This coolant is used for hot water heating and (potentially) for absorption refrigeration cycles. With a high concentration ratio and small PV cell,, the size of the modules dictates the allowable two axis tracking tracking error. For zero loss of direct irradiance on the cell, 900 μrad tracking error tolerance is allowed.

The technical challenges of this project are to produce a low-cost system that:

2.1. uses as much of incoming direct normal irradiation as possible in the production of electricity

2.2. allows as much diffuse incident irradiation as possible to enter occupied spaces for day-lighting

2.3. requires little or no maintenance

2.4. captures, as thermal power, that which is not directly converted to electric power via the PV cell

2.5. is aesthetically pleasant and unobtrusive (remove glare of focusing lens through diffusing ‘back shield’)

3. Results and Accomplishments

Through iterative modeling, a planar lens shape in a close packed array was determined (Figure 3) to ensure maximum conversion of solar energy to electrical power while permitting substantial day-lighting. The current prototype, a turntable type[3], achieves a maximum combined tracking error of less than 800 μrad. The modules and tracking mechanism are environmentally shielded from external forces, such as direct wind loading, by the exterior glass facade. Therefore, precise tracking can be achieved through inexpensive motors. The required rigid substructure on which the trackers are mounted is the building itself and adds nothing to the cost of the tracker. Attention has been paid to choice of materials to minimize or eliminate the problems of thermal expansion, creep and static friction.

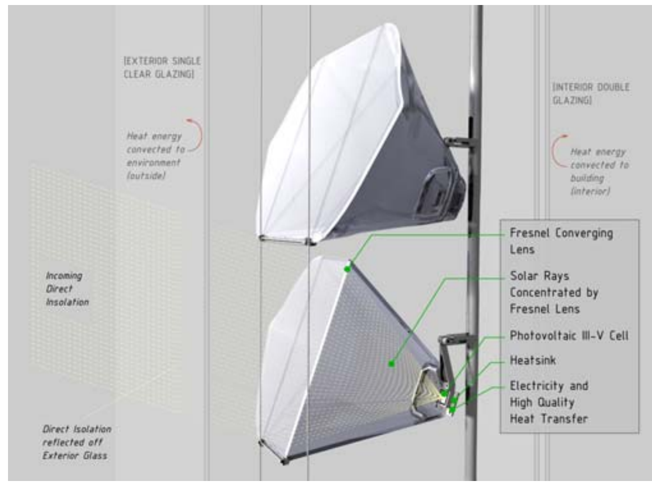

Figure 3. IC Solar Module Version 4.1.

4. Conclusions

The Rensselaer *IC Solar Façade System* is a building integrated photovoltaic system that substantially reduces the cost of solar energy by taking a dramatically different approach to existing flat plate or concentrating PV technologies to provide electrical power, thermal energy, enhanced day-lighting and reduced solar gain through the incorporation of translucent concentrating modules into double-skin curtain wall systems. This system presents the first effective and esthetically pleasing system that will permit the wide scale incorporation of building integrated photovoltaic power production in urban areas.

REFERENCES

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