Probing Solar Panel Design Systems

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Current drawbacks of utilizing solar energy are high initial costs and the inconvenience of high maintenance. Although the use of solar energy has been steadily growing, it is only 0.08 percent of the energy-producing market within the United States.[1] One of the growing areas in solar research has been the mounting brackets of solar arrays. The goal of this design project is to develop innovative methods for producing an inexpensive mounting system to reduce initial costs of a photovoltaic solar grid. Limited engineering research in this area has kept these panels retailing at the average cost of $600 per panel, while the mounting system costs per panel are over $100. Thus, this article will discuss possible cost-effective solutions for mounting systems. In addition, experimental methods for testing the panels will be suggested.

> *"Solar energy has an untapped potential ...current efficiency conversion from sunrays to electricity is only 12%"*

After reviewing current designs available on the market, an improved design was established by following these specific functionality requirements: (1) a mounting system to install on commercial and industrial flat roofs; (2) a simple and flexible design to facilitate mass production; (3) injected molded recycled plastic rather than traditional steel structures, to reduce corrosion on the system; (4) a simple and quick installation method such that individual panels can be easily removed; (5) a freestanding system that eliminates the need to penetrate roof seals; and (6) a wind rating to conform to building code specifications.

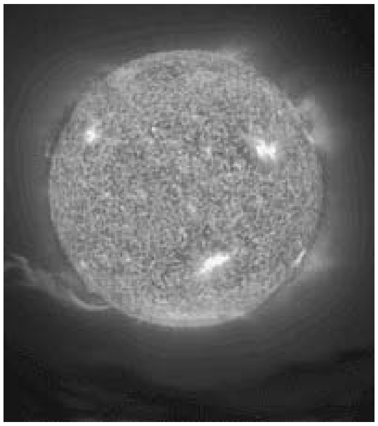

Image courtesy of SOHO/EIT consortium. SOHO is a project of international cooperation between ESA and NASA.

The following sections will discuss four possible designs of solar mounts for different applications. The Modular design meets all of the above functionality requirements and is intended for heavy winds. The second design, Corners, is more flexible; however, it will not protect the panels under heavy loads. For greater solar conversion efficiency, the Tilt design yields the best results. The last design, Awnings, aims to be visually exposed and uses novel materials.

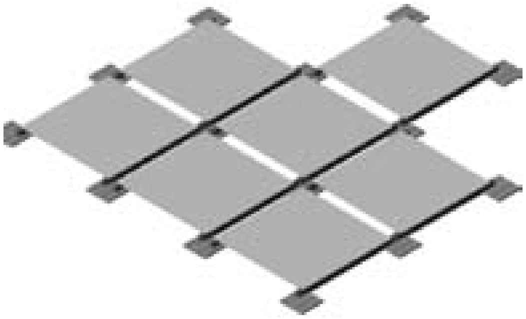

Figure 1. Modular array of seven panels.

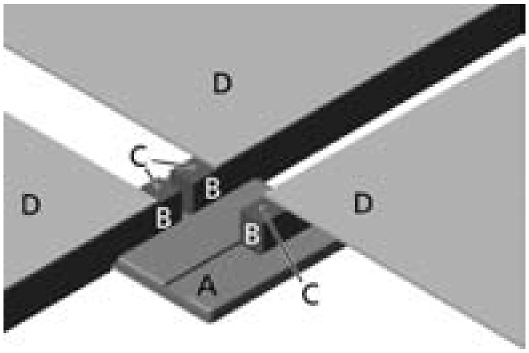

Figure 2. Parts identification of foot (A), slats (B), bolts (C), and panels (D).

Design I — Modular

The initial design is simple yet robust, and is composed of only two elements, a foot and slat. As shown in Figure 1, the panels are mounted to slats that are joined by feet. The grooves in the foot component shown in Figure 2 constrain the slats from rotation. A single stainless steel bolt constrains the slat in the vertical as well as lateral axes.

As with traditional mounting systems, the panels are glued to the slats. The installation costs are greatly reduced because there is no on-site customization for oddly shaped roofs; that is, the panels can be arranged in several configurations to adapt to roof obstructions. When mass-produced, the foot and slat components cost less then $3 each, and the total cost per panel is about $18. For smaller-scale production runs, a wood/plastic composite lumber could be used as an alternate material to injected molded plastic. This composite material is corrosive-resistant and can be cut and drilled similarly to wood.

This design meets all of the functionality requirements named previously, except for the 90 mph wind rating of Massachusetts building codes, which has yet to be proven. Due to the complications in theoretically modeling the system, an experimental model has to be made of air flowing over the top of commercial buildings, and the lift and drag forces on the system must be measured. Because the weight of the panels is not sufficient for keeping the system stationary, the corners of the array have to be constrained by cable stays that can be mounted to the side walls of the roof. The aims of this experimental test are to determine the necessary constraining forces as well as to find any system complications such as resonance frequencies that may arise in storm conditions. Once the forces are calculated, finite element analysis software can be used to specify the contact stresses in the glass panels.

The high wind-speed conditions on the roof of a commercial building will be simulated at the MIT water tunnel. The schematic in Figure 3 shows a delrin structure simulating the flow of air over a commercial building. The tunnel is 1.2 meters long and has a cross section of 0.5m x 0.5m. The water flows over the bulkhead to simulate the walls around the roof of a commercial building. The one-third-scale panel in the experiment is a stainless steel plate of dimensions 0.64m x 0.32m x 0.008m. As the water flows over the bulkhead, water can flow above and below the panel because there is a clearance of 0.01m to simulate ventilation under a panel. To vary the position of the panel, the distance between the

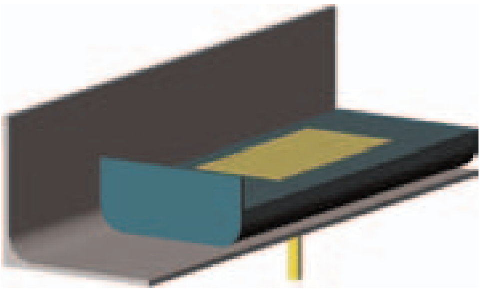

Figure 3. Experimental schematic cutaway of tunnel section. The water flows from left to right at a maximum velocity of 5m/s. The distance between the panel and bulkhead can be adjusted up to 0.64 meters.

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Using nondimensional analysis, the medium and scaling properties can be simulated for the actual conditions. The Reynolds number in Equation 1 can be used to equate the actual and simulated conditions.

$$\mathrm{Re} = \frac{r \Diamond v \Diamond L}{m}$$

Equation 1. Reynolds number, where r is the density, v is the velocity, L is the width of the panel, and m is the viscosity.

The forces on the panel will be measured using a six-degree-of-freedom dynometer that is positioned below the water tunnel. The measured vertical and horizontal forces can be scaled appropriately by using the coefficient of lift and drag in Equations 2 and 3, respectively:

$$C_L = \frac{F_L}{0.5 \Diamond r \Diamond v^2 \Diamond A}$$

$$C_D = \frac{F_D}{0.5 \Diamond r \Diamond v^2 \Diamond A}$$

Equations 2 and 3. Lift and drag coefficients, where F_L is the vertical force, F_D is the horizontal force, v is the velocity, and A is the area of the panel perpendicular to the force.

Design II — Corners

For every design there are revisions for different applications. In this case, the customer has dictated the creation of the three subsequent designs. MIT facilities recently received a grant to install solar panels on campus.[2] The supplier of solar panels uses various panel sizes that are not compatible with the Modular design. It would therefore be necessary to have shorter or longer slats depending on the specific size of the panel as there is not one industry standard. This issue spurred the idea of having a configuration that is not constrained by the specific dimensions of the panel. Removing the slats and modifying the foot component developed a design whereby the panel is only constrained in the corners. As shown in Figure 4, the corners of the panel are sandwiched in between two symmetric parts.

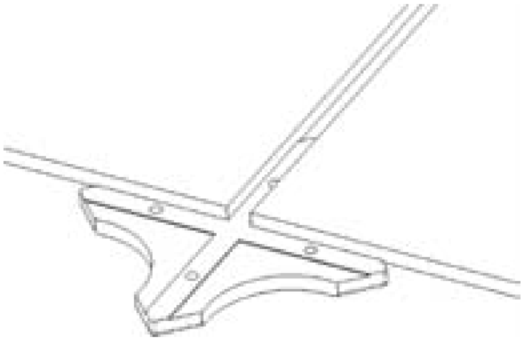

Figure 4. Depiction of bottom corner component with panel. The corresponding symmetrical corner component is not shown.

Figure 5. Array of panels with corner design depicting partial installation.

To reduce possible concentrated stresses on the extremely inelastic glass panels, a thin layer of neoprene can be inserted between the plastic and glass. The installation efforts are also reduced with this design because the gluing phase is eliminated. The drawback is that a small portion of the photovoltaic cells are blocked off from sunlight. In addition, the system is not as robust as the first: The slat backing does not fully support the panels. Under high winds, vibrations may dangerously strain the panels, reducing the life of the photovoltaic cells.

Design III — Tilt

These first two designs were economically driven, streamlined systems. This next design aims to variably tilt the panels to “follow the sun,” which can increase photovoltaic efficiency up to 40 percent. As the sun travels from east to west, tilting the panels in one axis will increase efficiency by 20 percent. In the northeast region of the United States, the sun also moves north and south, yielding another 20 percent increase in efficiency if the panels are tilted in a

References

1. Energy Information Administration. Renewable Energy Annual 2000. March 2001.
2. MIT News Release. Grant funds solar power project on and off campus. Oct. 24 2002.

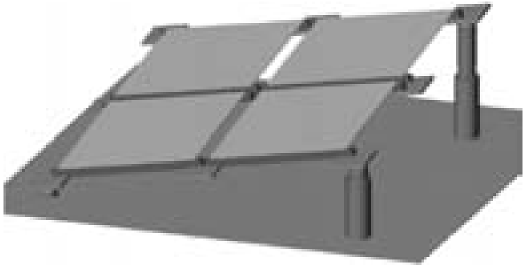

Figure 6. Schematic of a four-panel tilted array. Pneumatic actuators are positioned in two of the corners (right side).

second axis. The modular design with slats can be altered by adding two moving actuators in adjacent corners of a square array. These actuators could be comprised of either a lead screw configuration or an air piston driven by an air compressor, depicted in Figure 6.

The tracking control system could be composed of either an optical tracker or a scheduled position based on the given day of the year. Because these panels are elevated, there are additional bending stresses due to the weight of the panels. This will dictate brackets in addition to the foot components or even slats that extend the length of the array. The limiting factor of this more glamorous design is based on the added fixed cost of the movable parts as well as the marginal costs of the added energy consumption.

Design IV — Awnings

Besides the economic barriers, solar energy awareness has been extremely limited. One of the aims of the MIT solar panel project is to make the panels visible to everyone on campus. Consequently, the first three designs are limited to isolated roofs. A fourth design would place the panels on the south sides of buildings to resemble awnings. The construction would be a wood/ plastic composite lumber as supporting brackets, with alternative foot junctions.

Conclusion

The creation of better solar panel mounting systems has been a growing development in the solar energy industry because they provide electricity during peak midday usage and can be installed on small scales. This independence decreases the strain on electricity grids and eliminates the energy loss of distributed energy.

The current efficiency conversion from sunrays to electricity is only 12 percent, and once more research is invested in development this efficiency can increase. If the initial cost of installing a solar panel array is decreased due to improved mounting systems, more solar packages will be purchased, increasing the market size. As the solar energy industry expands, more profits can be cycled back into R&D to increase the photovoltaic efficiencies. The Massachusetts Renewable Energy Trust has given MIT facilities a grant to install solar panels on and off campus to increase the efforts of promoting solar energy. Ultimately, producing a solar panel package that is competitive to fossil fuels is a long-term goal that can only be achieved once this novel technology becomes mass-produced.

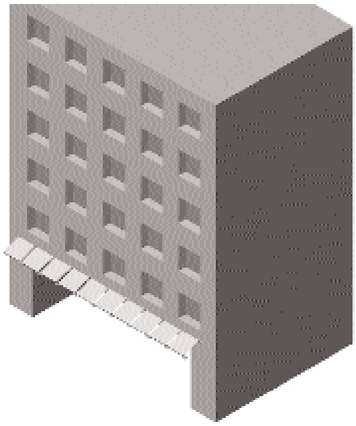

Figure 7. Awning mounting system installed on the south side of a concrete building for maximum sun exposure and visibility.

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