Flow Simulation Improves Photovoltaic Solar Panel Performance

Photovoltaic cells play a key role in the home energy market which, according to a recent report, could provide 30 to 40% of the United Kingdom's energy supply by 2020. Today's photovoltaic panels convert about 15% of the energy they capture from the sun into electricity, leaving 85% to be dissipated as heat. This creates a major thermal design challenge since every degree of temperature rise in the photovoltaic panels reduces the power produced by 0.5%. Schueco, one of the leading producers of photovoltaic panels, has met this challenge by using computational fluid dynamics (CFD) to redesign its photovoltaic panels so that they more efficiently utilize natural convection to cool themselves. The redesigned panels make it possible to utilize 15% to 20% more panels in a given space while maintaining the same temperature as the previous generation. "As the first photovoltaic panel manufacturer to utilize CFD simulation, we have gained a significant competitive advantage by being able to generate more power in a given space without allowing excess temperatures to reduce photovoltaic efficiency," said Hamid Batoul, Technical Director of Solar Department, Schueco International, Paris, France.

Microgenerator sales growing at a rapid rate

A growing enthusiasm for renewable energy has spurred the sales of small scale power generators, sometimes called microgenerators that can provide a portion of a home or business' power needs and in some cases also generate income by exporting the power they produce onto the grid. Energy from the sun does not depend upon uncertain supplies and potential price rises in nonrenewable sources of energy such as petroleum or natural gas. The UK government sponsored Energy Saving Trust estimates that microgeneration could reduce the UK's carbon emissions by 15% compared with the present mix of energy generation. So it should come as no surprise that global sales of photovoltaic panels and other microgeneration solutions are growing by more than 20% per year. The Rocky Mountain Institute in Snowmass, Colorado recently released a study that showed that output of small scale power sources will soon outstrip the world's nuclear power industry. A key driving force in the growth of photovoltaic microgenerators is incentives such as government-set prices for selling power back to the grid that make it possible for a photovoltaic system to pay for itself in only seven years.

Figure 1: Typical photovoltaic roof produced by Schueco.

Schueco provides complete solar energy systems for residential and commercial installations. The Schueco solution includes all components needed to produce energy from the sun including panels, collectors, tanks, mounting system, control units and monitoring electronics. Sunlight hits the photovoltaic panels and generates direct current. The switch protects the solar modules from grid power fluctuations. The solar direct current goes from the panels to an inverter which converts it to AC current for household use. If there is extra solar current, the system feeds it to the utility grid, running the meter backwards. If more power is needed, the switch draws power from the utility grid. Getting everything from one source ensures interoperability and greatly simplifies replacements and upgrades. It also means that the different elements of the solar energy system are optimized to deliver the best total performance. Schueco photovoltaic panels can be installed on top of an existing roof, integrated with the roof, take the place of a sloping or flat roof, serve as a partial or complete façade if no roof surfaces are available and be installed on canopies

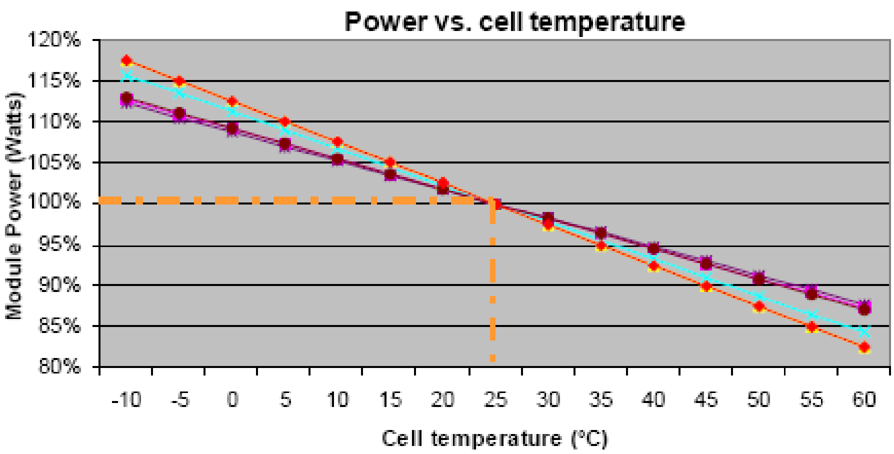

Figure 2: Module power decreases as temperature rises

Thermal design challenge

A major design challenge for Schueco and other manufacturers of photovoltaic panels is keeping them cool. The power generated by panels decreases as their temperature increases at a rate of about 0.5% per degree Centigrade at a temperature above 25^{o}C. Adding forced air cooling adds to cost and maintenance requirements and consumes a significant amount of energy generated by the cell so nearly all photovoltaic panels are cooled solely by natural convection. The modules are constructed so that air can flow under the panels in order to maximize convective cooling. The geometry and construction of the solar energy system can have a major impact on how effectively the panels are cooled. Engineers in the solar energy business typically use engineering calculations, experience and intuition to design panels to maximize cooling effectiveness. They build each design and then test it under various ambient conditions to determine temperatures at various locations. The problem with this approach is that the constraints of the design process usually only make it possible to investigate a small number of configurations from a thermal standpoint. The result is that the design is far from optimized from a thermal standpoint.

Schueco was the first company in the solar energy business to recognize that substantial improvements in photovoltaic panel performance could be achieved by optimizing thermal design. The company borrowed from the experience of the electronics original equipment manufacturers that also face major thermal challenges and use CFD to analyze the airflow and heat transfer through their products. A key advantage of computer simulation is that a proposed design can be simulated in a fraction of the time that would be required to build and test it. Another advantage is that CFD provides diagnostic information such as the airflow, pressures and temperatures at any point in the simulation domain which helps understand the root causes behind the performance of a proposed design and often leads to rapid improvement. “I previously worked for several companies making telecommunications equipment and used thermal simulation to solve thermal challenges,” Batoul said. “I found that Flomerics’ Flotherm CFD software was the most powerful tool available in that space. Performing thermal simulation of solar energy systems requires different software because of the need to model building materials that play a role in thermal performance. Flomerics offers Flovent CFD software designing for addressing heating, ventilation and cooling problems in buildings. We tried Flovent and found it met all our requirements such as modeling the thermal characteristics of glass and simulating the effects of radiation on the panels."

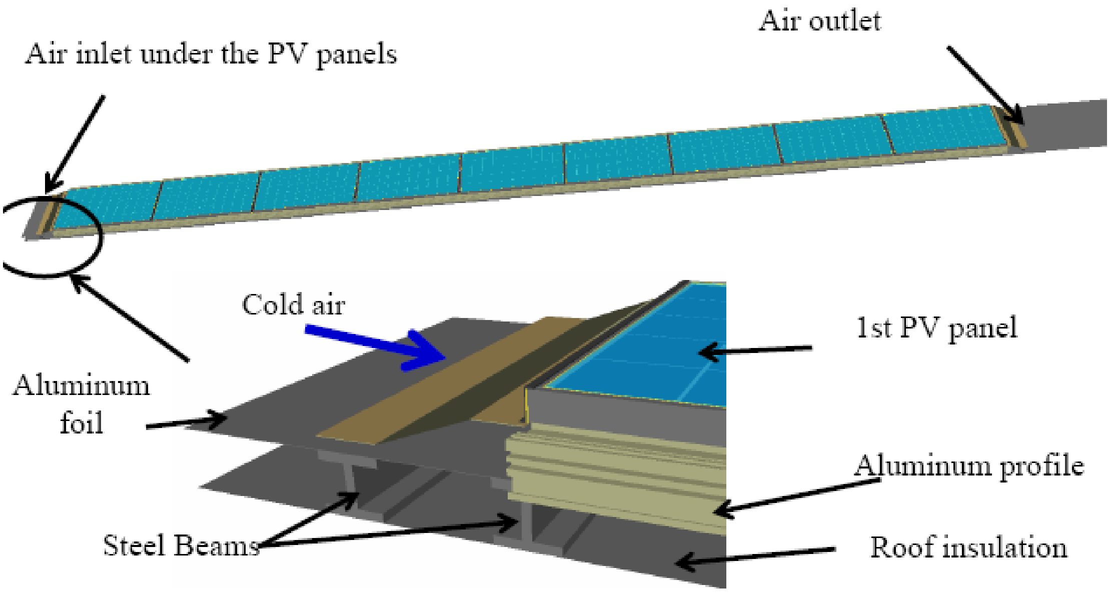

Figure 3: Complete solar energy system modeled with Flovent CFD software

CFD enables design optimization

Batoul uses Flovent to model complete solar systems in place on buildings. He uses Flovent glass elements to simulate the photovoltaic panels. He models the solar systems in their full detail including with the panels, aluminum profile panels, aluminum sheets used as backing for the panels and steel beams that connect the solar modules to the roof. Flovent simulates the absorption and reflection of solar energy by the panels, the transfer of heat to aluminum profiles and the surrounding air, etc. The simulation results show the convection driven flow of air from the inlet at the lowest point on the panels to the outlet at the highest point. The simulation shows the upper air layer picks up heat from the photovoltaic panels as it rises from the inlet to the outlet from the ambient temperature of 25°C to 37.6°C near the outlet as shown in Figure 4. Furthermore, the simulation shows the hottest temperatures are seen in the space between the panels where the temperatures are above 60°C as shown in Figure 5.

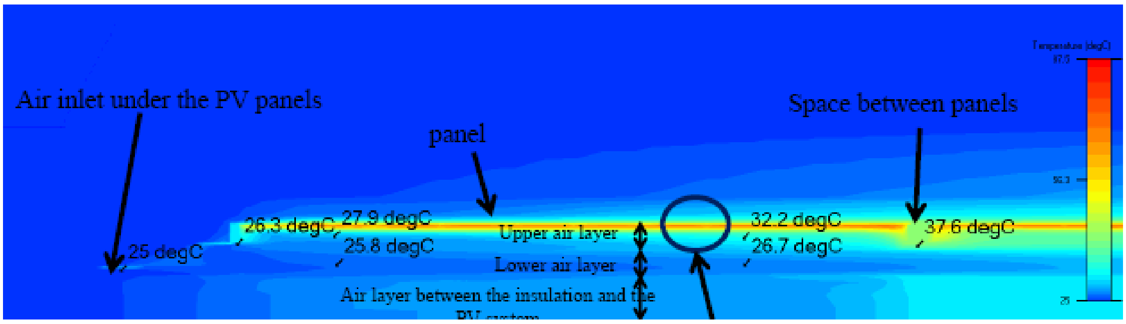

Figure 4: Air temperature between the photovoltaic panels

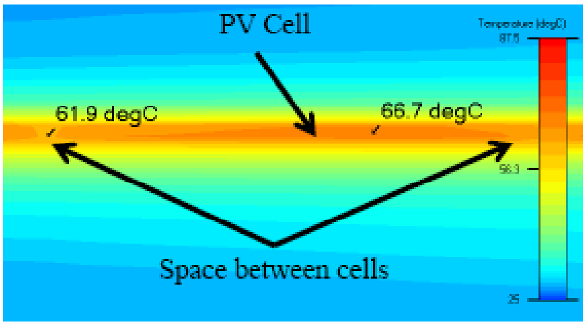

Figure 5: Zooming in shows the highest temperatures in the center of space between panels

“The CFD results helped us understand exactly how the panels were being heated and guided us as we made major improvements to the design,” Batoul said. “Examining the flow of air under the photovoltaic panels showed that the size of the passageway was constricting the flow of air. We increased the depth of the profile that supports the photovoltaic panels to increase the distance between the panels and the roof. Re-running the simulation demonstrated that this increased the airflow and reduced the temperature of the photovoltaic panels. We used simulation to study the performance of the revised design under a wide range of wind and temperature conditions. We also looked at different geometries for the inlets and outlets. We evaluated the effects of using different numbers and arrangements of photovoltaic panels. Through these studies, we optimized the design of the solar energy systems and also gained an understanding of how temperature is affected by different arrangements of panels and ambient conditions. For many projects we now run a CFD simulation to evaluate the temperature of the panels to ensure that they are running at optimal efficiency. As the first in our industry to perform CFD simulation, we believe that we are now able to provide our customers with substantially higher power output than an equivalent competitive design.”