A Simulation Study on the Energy Performance of Photovoltaic Roofs

H. Yang, Ph.D.
Member ASHRAE

Z. Zhu, Ph.D.

J. Burnett, Ph.D.

L. Lu

ABSTRACT

A simulation model has been developed to investigate the thermal and electrical energy performance of photovoltaic roofs (PV roofs). Direct numerical simulations of heat transfer and energy conversion of PV roofs are made by introducing a cumulative variable, which can simplify the heat transfer calculation problems. The cumulative variable is inverted to represent the roof surface temperature instead of real surface temperature so that it is easier to deal with thermal radiation heat transfer between the two-layer surfaces of the ventilated PV roofs. Natural ventilation heat transfer in the ventilation gap takes away a large amount of heat, which reduces the cooling load of the buildings. The cooling load reduction, the ventilation gap ratio, and the roof inclination angle are discussed in this paper. It is found that the cooling load component through a PV roof is about 35% compared with the load of a conventional roof.

INTRODUCTION

With increasing pressure for energy conservation and environmental protection, solar power generation using photovoltaics is now being regarded as a feasible way to use renewable energy resources. Photovoltaic integration in buildings, especially on building roofs, is gradually becoming more economical to use compared with conventional power generation. Many photovoltaic roofs (PV roofs) are now being developed around the world, but few detailed investigations of the thermal and electrical energy performance of the PV roof structure were found in a review of the literature. This paper analyzes the impact of the special structures on heat gains and cooling load components across PV roofs and the power generation conversion efficiency of the PV roof systems.

Many countries have initiated detailed programs to develop photovoltaic roofs. As reported by Haas et al. (1999), in order to reduce atmospheric pollution caused by electricity generation from conventional fossil fuels, a number of large programs have been launched with the support of governments, such as the 1000 PV roof program in Germany, the 200kWp PV roof program in Austria, and the worldwide program in Japan. A one million solar roof program has been initiated in USA. These programs will help with market penetration for this renewable resource, although the cost of PV modules is still high. It is the need for environmental protection, not just energy conservation, that forces policy makers to use renewable energy resources. It was reported by Spiegel et al. (1998) that a $10 monthly premium for electricity generated by renewable resources would be acceptable for about half of the United States' electric utility consumers. This means that PV power will continue growing rapidly in the new century.

Many researchers have studied the performance of photovoltaic applications, and there have been a few reports on photovoltaic claddings in building walls and roofs.

The leading issues of thermal regulation and basic design rules for installation of PV claddings were reported by Brinkworth et al. (1997). They found that by designing an air gap between the PV panels and the building roof, not only was the energy conversion efficiency improved, but the heat transferred into the building was reduced.

A Korean case study on building-integrated photovoltaics was carried out by Yoo and co-workers (1998). They analyzed the tilt angle and orientation effects on PV roof performance. An ideal tilt angle for a PV array installation in Korea may not be practical when aesthetics, cost, and safety features are taken

Hongxing Yang is an assistant professor, and **Lin Lu** is a doctoral student, in the Department of Building Services Engineering, Hong Kong Polytechnic University, Hong Kong. **Zuojin Zhu** is an associate professor in the Department of Thermal Science and Energy Engineering, University of Science and Technology of China, Hefei, China. **John Burnett** is a professor and chair of the Department of Building Services Engineering, Hong Kong Polytechnic University.