Int. J. Electrochem. Sci., 8 **(2013)** 12348 - 12352

International Journal of
ELECTROCHEMICAL
SCIENCE
www.electrochemsci.org

Note

Thermal Field Analysis of Building Materials Type Building Integrated Photovoltaics (BIPV) Devices

Hanmin Tian[1,2,], Hongyan Yang[2], Huiming Wang[1],Wenfeng Duan[2], Fenglan Tian[2]*

[1]School of Information, Hebei University of Technology, Tianjin, 300130 , P.R. China
[2]Beijing Oriental Yuhong Waterproof Technology Co., Ltd,Beijing, 100123,P.R. China
*E-mail: tianhanmin@hebut.edu.cn

Received: 27 November 2012 / *Accepted:* 22 May 2012 / *Published:* 25 September 2013

Thermal conductivity, thermal convection and thermal radiation analysis of BIPV block is necessary which directly affect the output voltage and conversion efficiency of solar cells. A practical theoretical model established a simulation for thermal field distribution of the actual BIPV blocks in a variety of thermal conductivity material characteristic, wind speed and other meteorological conditions.

Keywords: BIPV; thermal field; model; thermal conductivity

1. INTRODUCTION

Building Integrated Photovoltaic's(BIPV) are designed to be installed on house in the same with ordinary roofing materials and construction. It is directly use of solar energy with convenience, environmental protection, but also help to alleviate the scarcity of petroleum energy to address urban energy demand. From the development trend, the integration of photovoltaic and roof will become the mainstream.

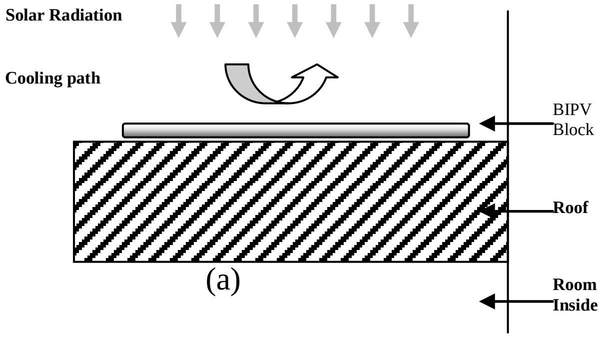
However, there are many issues to be resolved photovoltaic roof integration technology, one of which is that when the solar modules used as building blocks to cut back ventilation and cooling, ventilation or cooling of solar module is not good, the entire cell group pieces of the back of the temperature can be as high as 70 ℃ or more [1], which directly affect the output voltage and conversion efficiency of solar cells. The same solar cell life will be greatly affected[2]. In order to ensure the stability of the charging voltage output, the rise of temperature and the drop of solar cell square output must be considered in the design of solar module system, and then the series and parallel construction of solar modules are arranged. Therefore, thermal conductivity, thermal convection and thermal radiation analysis of BIPV block is necessary[1,3].

Here the mathematical model was built up which is the thermal radiation, convection and conduction of BIPV block under natural ventilation cooling, and the influence of different parameters on the system temperature are studied.

According to the law of conservation of energy, the differential equation of thermal conductivity of BIPV module under sunlight with air flow, were built both in one-dimensional and three-dimensional, by which the thermal simulation results field of BIPV module were obtained, with the condition parameters of solar radiation, environmental temperature, wind speed, and the scale of one board, the package structure, materials, thermal conductivity and other parameters. The conclusions are that the ambient temperature and the module size had a greater influence on the thermal field while thermal conductivity of the material relatively small. these achieved method and results are satisfactory in real-time, effectiveness, for some practical reference[4,5].

2. EXPERIMENTS

Thermal conductivity module of BIPV consists of BIPV block arrays, the roof, mounting bracket the air cooling flow path between the array and the outer wall, air inlet and air outlet, and solar radiation as shown in Figure 1.



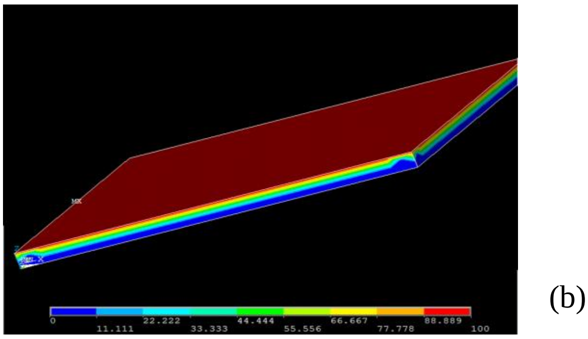


Figure 1. (a) thermal conductivity module of BIPV block; (b) thermal filed analysis of BIPV block

To calculate the heat of the composite BIPV structure, the key is to calculate the heat transfer through the composite structure during the outdoor air temperature and solar radiation to the BIPV tending towards stability[6,7]. The monocrystalline silicon solar cells are usually thin and relatively large surface area and the heat loss around the cell is relatively small. So that, the temperature almost does not change in the thickness direction perpendicular to the roof, the temperature only changes along the thickness direction, it can be seen as the temperature only along a direction of change, while ignoring the heat generated within the battery. A three-dimensional heat source thermal conductivity differential equations, as Eq 1shown:

$$\rho c_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left\{k_x \frac{\partial T}{\partial x}\right\} + \frac{\partial}{\partial y}\left\{k_y \frac{\partial T}{\partial y}\right\} + \frac{\partial}{\partial z}\left\{k_z \frac{\partial T}{\partial z}\right\} \quad 1$$

In Eq1, ρc_p the heat capacity of the material, k_n is the thermal conductivity of the material. The radiation of solar cell surface consists of sun's radiation, earth surface reflectance and infrared radiation of the earth, therefore, the boundary conditions is as following.

$$k_n \frac{\partial T}{\partial n} = a_s S \phi_1 (1\text{-}\eta) + a_s E_r \phi_2 (1\text{-}\eta) + \varepsilon_e E_e \phi_3 \text{-} \varepsilon_e \sigma T^4 \quad 2$$

The back and side solar cells are received the remnant sun radiation, roof surface reflectance and roof infrared radiation, so the heat transfer boundary conditions for

$$k_n \frac{\partial T}{\partial n} = a_s S \phi_1 + a_s E_r \phi_2 + \varepsilon_e E_r \phi_3 \text{-} \varepsilon_e \sigma T^4 \quad 3$$

In Equ 3, a_s: the sun absorption surface rate; S is the solar constant; E_r :the average solar radiation reflectance density of the earth surface; ε_e the average infrared radiation reflectance density of the earth surface; η: photovoltaic conversion rate; ϕ_X , ϕ_Y and ϕ_Z are solar radiation angle, the earthshine angle and earth red radiation angle.

According to the above theoretical derivation, $\rho c_p, k_n, a_s$ and ε_e are the main factors affecting the temperature distribution of a BIPV solar panel.

Based on these theoretical derivation and the thermal conductivity parameters of each materials and their size characteristics as listed in table 1, the thermal field analysis of building materials type BIPV devices are drowned as Fig 1(b).

Table 1. the thermal conductivity parameters of each materials and their size characteristics

material	Density ρ（kg/m³）	specific heat cp J/（kg·k）	thermal conductivity k	Thickness mm
glass	2500	945	5	5
EVA	938	700	0.54	0.15
Silicon cell	2330	900	150	0.2
Waterproofing sheet	980	2100	0.3	0.15
concrete	2550	920	1.65	1.5

3. RESULTS AND DISCUSSION

From the thermal filed analysis of BIPV block, some factors effecting thermal conductivity, thermal convection and thermal radiation are located. However, BIPV systems are usually integrated system which is a lot of parts ,such as various building structure units, solar power units solar building integration. These units need to connect and run in, involving many problems. So , on the basis of experiment and the real application, empirical constant adjustment to these thermal filed analysis is necessary.

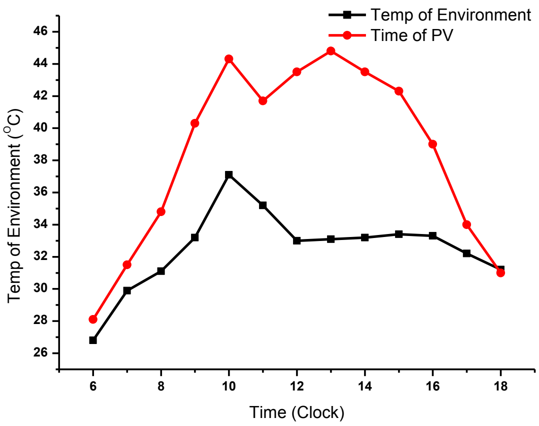


Figure 3. Temperature simulation of BIPV block

Thermal conductivity, thermal convection and thermal radiation analysis of BIPV block is conduced here with practical theoretical model, which can provide very good simulation for thermal field distribution of the actual BIPV blocks in a variety of thermal conductivity material characteristic, wind speed and other meteorological conditions. According to the theoretical derivation, the heat capacity of the material, the thermal conductivity of the material, the sun absorption surface rate, and the average infrared radiation reflectance density are the main factors affecting the temperature distribution of a BIPV solar panel.

4. CONCLUSIONS

We have studied the influence of different parameters on the BIPV system temperature. The conclusions are that the ambient temperature and the module size had a greater influence on the thermal field while thermal conductivity of the material relatively small. Furthermore, these achieved method and results are satisfactory in real-time, effectiveness, for some practical reference.

ACKNOWLEDGEMENTS
The authors would like to acknowledge financial support from Start Fund of Hebei University of technology, China postdoctoral Science Foundation funding(2011M500197) and Hebei province science and technology support program(10213946).

References

1. S. A.Omer, R.Wilson, S. B.Riffat, *Renewable Energy*,9(2003) 1387.

2. Basant Agrawal, Basant Tiwari, *Energy and Buildings*,9(2010)1472
3. Andreas K.Athienitis, James Bambara, Brendan O'Neill and Jonathan Faille, *Solar Energy*, 1(2011)139.
4. E. Skoplaki, J. A.Palyvos, Renewable Energy, *Renewable Energy*,1(2009) 23.
5. C. Y.Huang, H. J.Chen, C. C.Chan, C. P.Chou and C. M.Chiang, *Energy Procedia*,12(2011)531
6. Basant Agrawal, Basant Tiwari, *Applied energy*,2(2010)417.
7. Shuang-Ying Wu, Qiao-Ling Zhang, Lan Xiao and Feng-Hua Guo, *Energy and Buildings*, 12(2011)3558.

© 2013 by ESG (www.electrochemsci.org)