CYPRUS UNIVERSITY OF TECHNOLOGY

FACULTY OF ENGINEERING AND TECHNOLOGY

PhD Thesis

THERMAL ANALYSIS OF NATURALLY VENTILATED BIPV SYSTEMS

Agathokleous Rafaela

Limassol, November 2017

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FORM FOR APPROVAL

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by

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Cyprus University of Technology

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Abstract

The aim of this study is to investigate the thermal behaviour of naturally ventilated BIPV systems. This study focuses on the systems with natural ventilation because it is believed that there is a good potential to improve their performance with design configurations, in order to provide sufficient ventilation to circulate the air and avoid the use of a fan with extra cost, noise and maintenance requirements. The ultimate goal is to estimate the convective heat transfer coefficients in all sections of a BIPV system.

An extensive experimental analysis is carried out in outdoor environmental conditions and in indoor controlled conditions with the use of a solar simulator. It was pointed out that the air exits the duct at around 10^{o}C hotter than it enters and for this reason the PV's temperature increases from the bottom to the top. Regarding the inclination angles tested, it is observed that the system develops higher temperature when is inclined at 30^{o} and less when is placed vertically (90^{o}). Subsequently, an analysis of the natural convection is carried out using fundamental convection equations and as a result, two correlations for the estimation of the convective heat transfer coefficients (CHTC) are extracted for the first time. These can be applied to estimate the CHTC in the air gap between the PV panels and the outer skin of the building, in double skin BIPV systems, for windy and no windy conditions. Afterwards, a 3D computational fluid dynamic (CFD) model was built in COMSOL Multiphysics and it is validated with the experimental results. The general conclusion is that the experimental results were in a good agreement with the simulation results.

Additionally, based on the measured temperature distribution of the system from the experimental procedures, energy and exergy analyses are carried out and the correlations for the estimation of the energy and exergy efficiencies are presented for the first time for a naturally ventilated BIPV system. The energy efficiency of the system is estimated to be up to 26.5-33.5% while the exergy efficiency is estimated to be between 13-16%.

Finally, the gained knowledge is applied to a real BIPV demonstration system. A building simulation model is carried out to predict the temperature of the PV panels and the energy production of the system for one year. A good agreement is observed between the calculated and measured data.