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Energy Simulation and Parametric Analysis of Water Cooled Photovoltaic/Thermal System

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ABSTRACT: In this paper computerized simulation of water-cooled photovoltaic/thermal system has been investigated. The configuration of the selected system was a plate and spiral tube type. Energy simulation was done through code development in MATLAB software. The proposed model has been validated with practical data. Thereafter, overall performance of the system has been evaluated. Afterwards, parametric analysis was done in order to compare the effect of the variation of operational parameters on thermal and electrical energy efficiencies. To cover this aim, variation of overall efficiency and pressure drop have been investigated versus variation of water flow rate and the distance between tubes as well as the diameter of tubes. According to the results of simulation and analytical studies, the expected output can be specified logically with evaluation of operational and performance parameters. This procedure is a key step which should be considered for the optimal design of the system in different weather conditions considering energy efficiency improvements. According to the results of this research, for the simulated photovoltaic/thermal system following values shows the optimum amounts: water flow rate of 0.016 kg/s, the outer diameter of the water side pipe 1 cm and the distance between pipes in a range of 7 to 11 cm.

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1- Introduction

Photovoltaic Thermal (PV/T) system is a type of solar energy technology in which water or air is used to recover the heat from the PV panel. The main advantage of this system is the improved efficiency of the photovoltaic module. Water cooled type is a usual PV/T system, especially for the purpose of warm water generation in residential and commercial buildings. In this paper, a water-cooled PV/T system with spiral configuration has been simulated through code development in MATLAB software and based on energy analysis. Developed energy model has been validated by using experimental data of previous studies. Afterwards, three independent variables have been selected for parametric studies including mass flow rate, tube diameter, and inlet water temperature. Effect of mentioned parameters variation has been studied on the improvement of electrical and thermal energy efficiencies as well as system pressure drop.

2- Methodology

For the purpose of energy analysis of PV/T system, heat transfer phenomena were applied. Fig. 1 shows the thermal resistance circuit of the considered model. In this research, a PV/T system consists of crystalline PV panel.

In the presented model, temperature distribution is completely different from one tube to the other which is presented in Figs. 2 and 3.

Based on the developed model in each collector with spiral tubes for each element, useful heat has been modeled using energy equation and numerical method. A modeled collector consists of N parts and water flow temperature from each part is equal to the inlet water temperature of the next part. Simulation of the PV/T system was done through open source MATLAB software by code development. Model results have been evaluated and verified by the results of the laboratory simulation of Reference [4] and the calculation were done by using algorithm of Fig. 4.

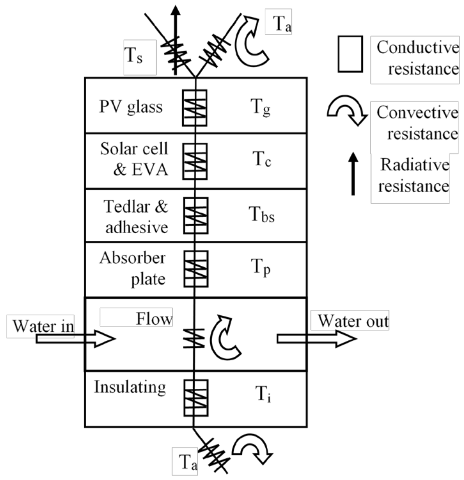

Fig. 1. Thermal resistance circuit diagram of PV/T [1, 2]

3- Results and Discussion

In Fig. 5, variation of overall efficiency with flow rate and distance between pipes is demonstrated. For the flows higher than 0.014 kg/s, flow regime is changed to turbulence condition and as a result, overall efficiency increased in higher flow rates.

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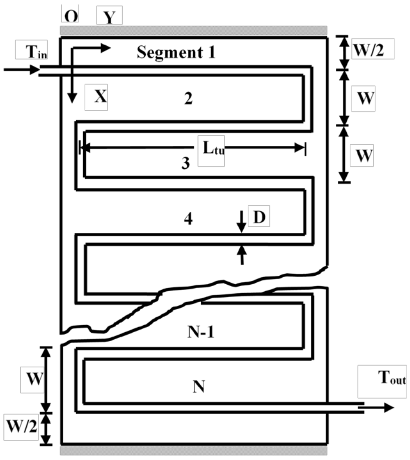

Fig. 2. Schematic diagram of absorber plate and serpentine tube [3]

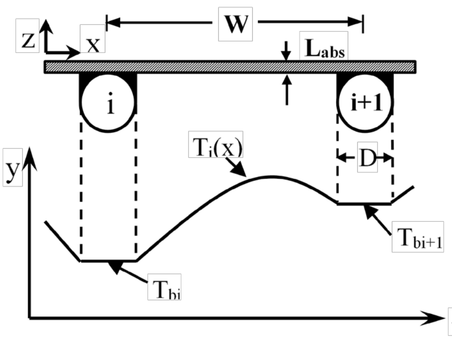

Fig. 3. Temperature distribution of plate between segments *i* and *i*+1 [3]

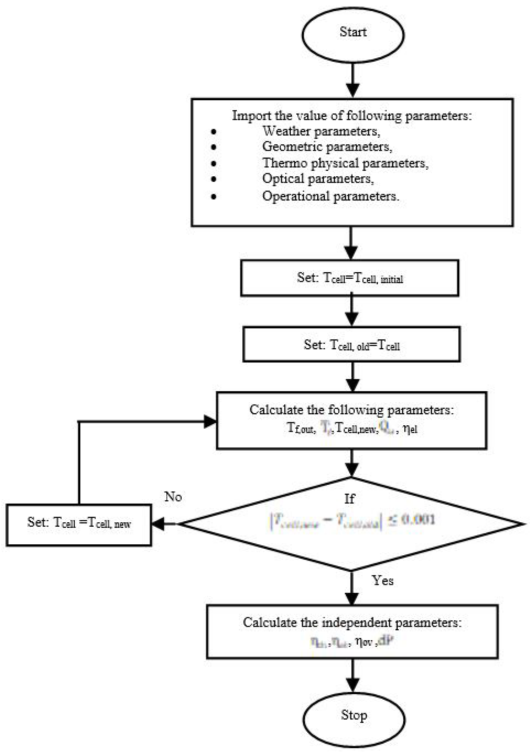

Fig. 4. Thermal and electrical energy efficiencies calculation algorithm in developed model

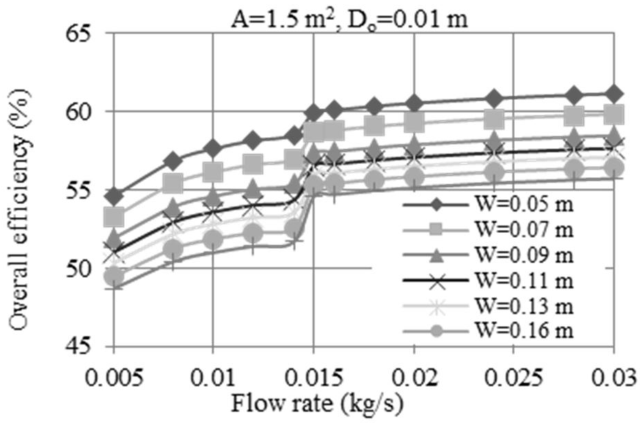

Fig. 5. Variation of overall efficiency with flow rate and the distance between pipes

Fig. 6, shows the variation of pressure drop with changes in flow rate and the distance between pipes. This variation is similar to the variation of overall efficiency due to the effect of flow regime change. As a result pressure drop is higher than 15 kPa for the lower distance between pipes.

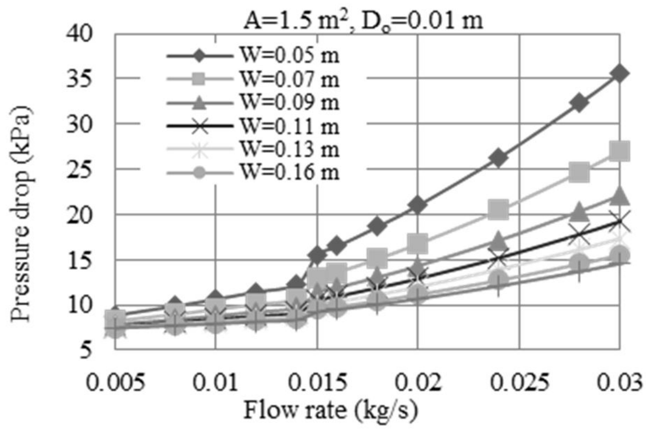

Fig. 6. Variation of pressure drop with flow rate and the distance between pipes

In terms of designing, a reliable PV/T system should have higher overall efficiency and lower pressure drop. In Figs. 7 and 8, variation of overall efficiency and pressure drop were illustrated versus changes in flow rate and pipe diameter. It

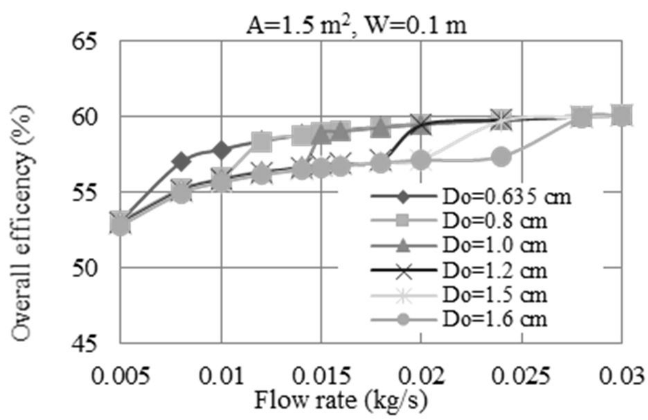

Fig. 7. Variation of overall efficiency with flow rate and pipe diameter

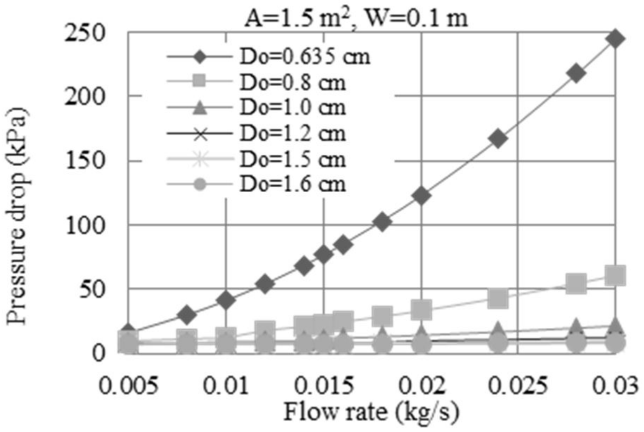

Fig. 8. Variation of pressure drop with flow rate and pipe diameter

can be concluded that, variation of overall efficiency is less dependent to pipe diameter. However, pressure drop in pipe diameters less than 1 cm is considerable. Regarding overall efficiency, by increasing diameter in higher flow rates, flow regime is changed from laminar to turbulence. Therefore, the appropriate choice would be lower diameter with lower pressure drop.

4- Conclusions

According to the results of this research, thermal energy and electrical efficiencies of the modeled water cooled PV/T is 40-50% and 10%, respectively. Regarding the parametric study, overall efficiency of the system is improved through increasing of flow rate, decreasing of pipe distance as well as decreasing of pipe's diameter. However, analysis shows that in higher flow rates will result more pressure drops. In addition, the less distance between pipes and lower pipe diameter will result in higher pressure drop.

Considering the evaluation of the modeled PV/T in evaluated climate conditions, the following values are the optimum amounts:

- Water flow rate: 0.016 kg/s;
- Outer diameter of the water side pipe: 1 cm;
- Distance between pipes: 7 to 11 cm.

In order to achieve better operational performance, outcomes of this study can be used in the design phase of the PV/T system. Following to this research, design, and construction as well as practical evaluation of the PV/T system will be done by the research team.

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