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A study of photovoltaic thermal (PV/T) hybrid system with computer modeling

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Abstract

Photovoltaic thermal hybrid system has a device that can provide the electrical power and hot water at the same time. The simulation model of photovoltaic thermal hybrid system has been created using TRNSYS tool in this paper. The simulation model can provide the transient and long term evaluation to predict the system performance in different weather conditions. The performance of 1.44 kW Photovoltaic thermal hybrid systems has been evaluated in different locations in Taiwan. The results shown the system electrical efficiency was 11.7~12.4% and thermal efficiency was 26.78~28.41%.

Keywords: Photovoltaic thermal, TRNSYS, simulation

1. Introduction

Photovoltaic thermal hybrid system (PV/T) has a system combines the solar thermal and electrical power at the same time. The PV/T system can be classified in water and air depending on the differential working fluid and in glazed and unglazed cover. Hung *et al.* [1] developed an integrated photovoltaic and thermal solar system (IPVTS) consisted of the PV/T collector, storage tank, pump and controller. The daily average thermal efficiency reaches 0.38 and the daily overall efficiency reached 0.5. He *et al.* [2] developed the natural circulation PV/T system and the daily thermal efficiency of PV/T system is about 0.4 and the daily overall efficiency is up to 0.55. Simulation tools have less development in PV/T system. TRNSYS is popular tool in renewable energy as solar thermal, Photovoltaic and HVAC etc. Unglazed photovoltaic thermal collector simulation model has provided in TRNSYS. J. Bilbao *et al.* [3] study the flat plate PVT model using TRNSYS type 50 and modified model to compare the performance. P. Dupeyrat *et al.* [4] applied the TRNSYS simulation the Solar thermal and PV/T system and show the PV/PVT has good energy performance than PV/ST system at limited installation area. Xingxing Zhang *et al.* [5] shown the classification with different fluid applications including air based, water based, refrigerant based, and heat pipe based in the solar photovoltaic thermal module or system technologies. The nature convection photovoltaic thermosyphon water heating system can be applied with aluminium-alloy flat box and the electrical efficiency is 10.3~12.3% and the thermal efficiency is 37.6~48.6% in summer and winter day [6].

In this study, the 1.44 kW capacity of PV/T hybrid system has been installed in ITRI in Taiwan. The PV/T system combine with six pieces PVT modules that have un-glazed copper tube and sheet and a 500 l the storage tank using water to cool the module and recycle the heat. The simulation model of PVT system with TRNSYS has been created according to the real system. The simulation model can predict the system performance in different site with local methodology data. Fig. 1 has shown the photovoltaic

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thermal hybrid system in top of building in ITRI in Taiwan and the hot water can be applied in washing in the restaurant.

Fig. 1. 1.44kW/500L photovoltaic thermal hybrid system.

2. System Description

2.1. Simulation model in TRNSYS

Within TRNSYS tools, the photovoltaic thermal hybrid system can be modeled with transient and long-term period. The system has composited unglazed flat-plate PV/T collector, storage tank, pump, temperature differential controller and local weather data. Fig. 2 has shown the photovoltaic thermal hybrid system relation with TRNSYS tool.

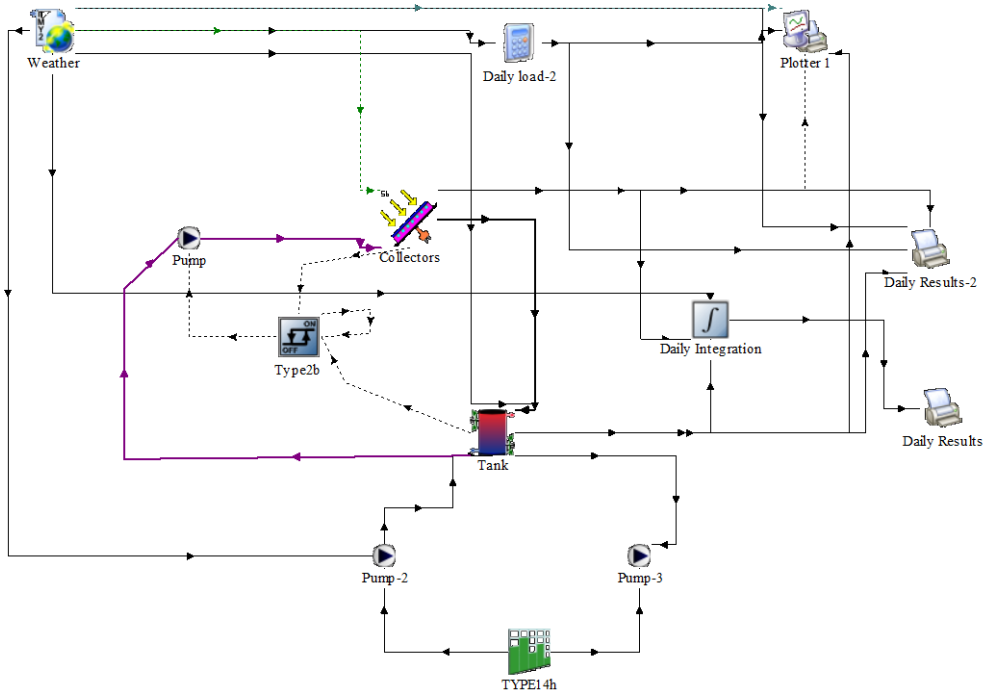

Fig. 2. Photovoltaic thermal hybrid system in TRNSYS.

PVT collect or model in TRNSYS has the dual purpose of creating power from embedded PV module and providing heat to a fluid passing through the copper tube bonded to metal sheet. the heat recycle from PV module can cool the PV module allowing high electrical power output and provide the hot water to apply in domestic heating, swimming pool or industrial preheating. Table 1 has provided the TRNSYS types of the PV/T system.

Table 1. List of the TRNSYS types used in the PV/T system simulation deck

Component	Type	Comments
Controller	2	Temperature differential control
PVT collector	563	Unglazed tube-sheet
Weather data	109	
Pump	3	
Tank	4	Storage tank

2.2. Parameters in TRNSYS

The parameters of hybrid PV/T system in TRNSYS has shown in Table 2.

Table 2. Design parameters in TRNSYS

Component	Description	Value
PV/T module	Module area	9.78m^2
	Thermal conductivities of the absorber	200 W/m-℃
	Fluid specific heat	4.18 kJ/kg-℃
	PV efficiency at reference condition	14.74%
	PV cell reference radiation	1000 W/m^2
	PV cell reference temperature	25℃
	Temperature coefficient of solar cell efficiency	0.0042 /℃
	Packing factor	1
Pump	Maximum flow rate	4LPM
	Maximum power	300W
Storage tank	Volume	500 l

The system performance can be calculated with solar radiation (kWh/m^2) H, PV/T electrical power (kWh) P and thermal capacity of water (kWh) Q at simulation period time. The system performance calculation is as follow:

The photovoltaic conversion efficiency:

$$\eta_{el} = \frac{P}{H \times A} \tag{1}$$

The thermal efficiency:

$$\eta_{th} = \frac{Q}{H \times A} \tag{2}$$

2.3. Verification of simulation model

The simulation model can be verified using real experiment data. The water temperature with simulation model is very close to the experiment data as Fig. 3.

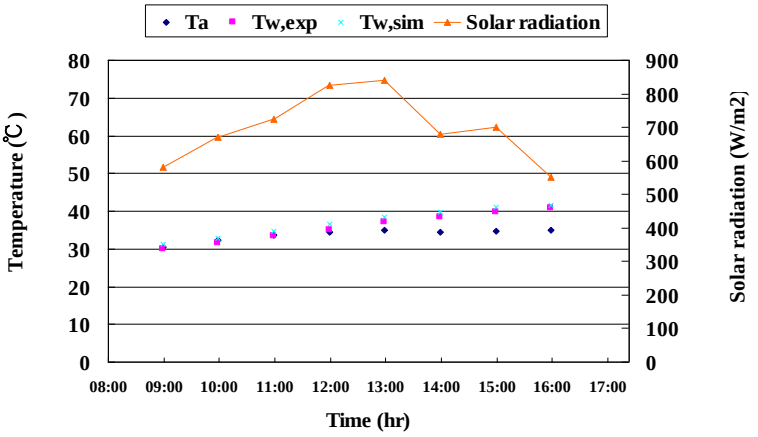

Fig. 3. The relation of temperature of water with experiment and simulation.

3. Results and Discusses

The PV/T system can provide the electrical power and hot water from solar energy. The operation of pump control according to the differential temperature between water temperature and module temperature controls the switch ON or OFF. Fig. 4 shown the water temperature in the storage tank can rise from 27℃ to 40℃ at one spring day.

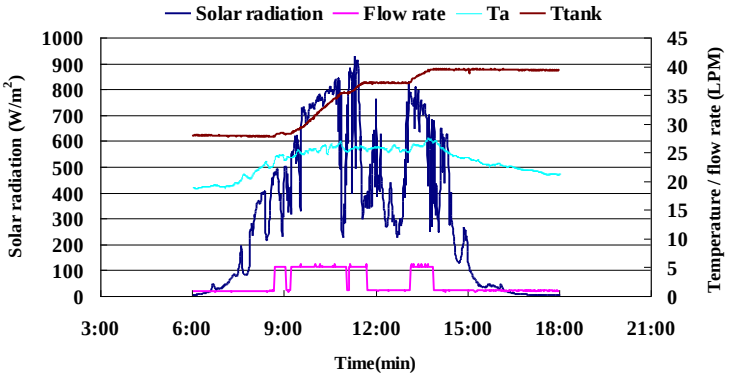

Fig. 4. Thermal performance of photovoltaic thermal hybrid system.

TRNSYS model has created to simulate the performance of electrical and thermal in this study. In Taiwan, the solar irradiation and the ambient temperature in south Taiwan are higher than north Taiwan. This study uses TMY2 data of different location to simulate the electrical and thermal energy production and efficiency. Table 3 shows the system performance in different city in Taiwan. The results shown the Tainan has best electrical efficiency and thermal efficiency than the other city.

Table 3. List of the system performance in different city in Taiwan

Parameters	Taiwan Taipei	Taiwan Hsinchu	Taiwan Taichung	Taiwan Tainan	Taiwan Kaohsiung
PV surface area (m^2)	9.78	9.78	9.78	9.78	9.78
Solar irradiation (kWh/m^2-year)	1060	1189	1255	1304	1348
Electrical energy production (kWh/year)	1261	1361	1490	1583	1599
Electrical efficiency (%)	12.16	11.70	12.14	12.41	12.13
Thermal energy production (kWh/year)	2776	3243	3411	3623	3616
Thermal efficiency (%)	26.78	27.89	27.79	28.41	27.43

4. Conclusion

Photovoltaic thermal hybrid system has a device that can provide the electrical power and hot water at the same time. The simulation model of photovoltaic thermal hybrid system has been created using TRNSYS tool in this paper. The simulation model can provide the transient and long term evaluation to predict the system performance in differential weather condition. The performance of 1.44kW Photovoltaic thermal hybrid system has been evaluated in differential location in Taiwan. The results shown Tainan in Taiwan was good place to install the PVT system better than another location in Taiwan. The simulation results shown the system electrical efficiency was 11.7~12.4% and thermal efficiency was 26.78~28.41%.

Acknowledgements

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