Solar photovoltaic/thermal system for Thai hospital

Presented in The 2nd Progress in Advanced Materials: Micro/Nano Meterials and Applications

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Abstract

The first system of Thailand was installed at Banglamung Hospital, Chonburi. Its application is to provide hot water for washing infected cloths. The major components of the system are PV/T collectors of 48 m^2 gross area and a hot water storage tank of 2,500 litres. The daily productions are the heat of 518 MJ/day and the electricity of 11 kWh/day with the system efficiency of 39%. To simulate the annual performance, it shows that the system efficiency is 43%. To compare with the separate systems of PV system and solar water heating system (SWH), the cost of electricity is 19.25 Baht/kWh, higher than the cost of PV system, and the cost of thermal energy is 1.61 Baht/kWh, better than SWH system. The separated systems provide the better economics results but the larger total area. Economics analysis of the PV/T system shows that it can replace diesel oil and electricity from grid.

Keywords: PV/T, photovoltaic/thermal, collector

1. Introduction

Solar radiation at Chonburi is about 19.82 MJ/m^2/year (Janjai, 2002) that is good for installing photovoltaic systems. However, the price of these systems is high obstructed to extend the market in Thailand. The yields of these systems can be better by extracting the undesirable heat produced by PV and causing low efficiency to use with another application such as water heating.

In this study, the PV/T system was installed at Banglamung Hospital. Its application is providing hot water for washer machines consuming hot water of 60 °C around 3,500 litres/day and electricity connected to grid. The system comprises $48m^2$ of PV/T collectors, with an electrical capacity 3.1 kWp, a 2,500 litres of water storage tank, pumps, and piping.

2. Experiment

2.1. PV/T collector

Two PV panels are attached on the top of the aluminum absorber by the high thermal conductivity epoxy. The copper pipes are attached to the back of absorber reducing heat loss with rock wool. The case is made of stainless steel to withstand the rust, and has a low iron tempered top glass cover to reduce heat loss by the wind.

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2.2. Data analysis

The inlet and outlet temperature of collector and storage tank were measured with thermocouple type K. The water flow rates were also measured. These for calculating thermal energy output of this system while the input, solar energy, was measured by pyranometer installed parallel to the collector. To find electrical energy output, voltage and current were measured. All measured data are recorded every 10 second and are converted to hourly basis. The collector efficiency (ASHRAE, 1986) and the PV efficiency (Garg and Agarwal, 1995) equations are shown as follow.

$$\eta_c = F_R\left((\tau\alpha)_e - U_L\frac{T_i - T_a}{G_t}\right) \quad (1)$$

$$= \frac{m_c C_p (T_o - T_i)}{A_c G_t} \quad (2)$$

$$\eta_{PV} = \frac{\sum_{i=1}^{n} P_{m,i}\Delta t}{\sum_{i=1}^{n} G_{t,i}\Delta t\ A_c} \times 100\% \quad (3)$$

The PV efficiency was increased in the morning when solar intensity increased and it tended to constant from 10 am. to 3 pm. that the solar intensity was mostly more than 600 W/m^2. Then, it decreased in the evening. Maximum hourly PV efficiency was about 5%.

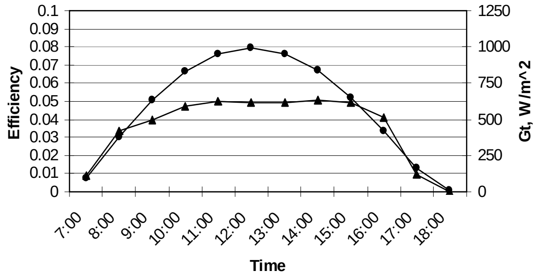

Figure 1. Hourly electrical efficiency

The circulating pump operated from 9 am. to 4 pm. so, out of this period, the collector efficiency was zero. It rose up from 9 am. to 10 pm. then it lowed down until noon. After that, it increases again until 3 pm. and then it decreased. Inlet water temperature of collector effects collector efficiency, higher solar energy at noon causes higher inlet water temperature so, collector efficiency is decreased.

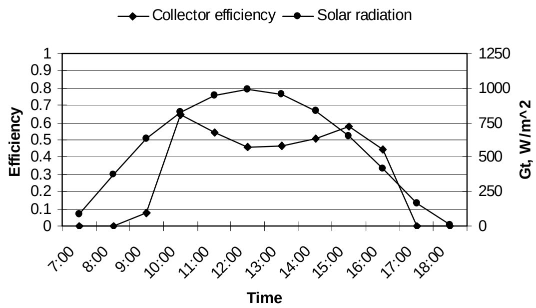

Figure 2. Hourly thermal efficiency

From equation (1) and (2) the collector characteristics is shown as follow and the electrical characteristics also.

$$\eta_c = 0.6854 - 4.5415\left(\frac{T_i - T_a}{G_t}\right) \quad (4)$$

$$\eta_{PV} = 0.064[1 - 0.0028(Tpv - 25)] \quad (5)$$

The system generates heat around 518 MJ/day and electricity about 11 kWh/day.

3. Annual yields

3.1. Energy Production

TRNSYS program was used to estimate energy production. The maximum monthly average temperature was 51.5 °C in May and the minimum monthly average temperature was 47 °C in September.

The PV/T collector received thermal energy around 40% of solar irradiation. Thermal energy delivered was around 80% of thermal energy collected by collector. Electrical energy generating was only 3.2% of solar irradiation. The system efficiency was 43.3% by providing 134 GJ/year of heat and 3 MWh/year of electricity.

3.2. GHG Emission Reduction

From the annual yield of PV/T system, the total electricity reduction from grid was 40 MWh/year. By RETscreen simulation and fuel mix of Thailand in 2002 (EGAT, 2002), the GHGs emission reduction of the PV/T system at Banglamung hospital was 22.5 ton CO_2/year.

4. Economics analysis

The total cost of the PV/T system installed in Thailand is about Baht 1,600,000 for a system capacity of 3.2 kW_p. The simple pay back period is 10 year while the annual saving is Baht 104,000. This shows that PV/T system is better economics than PV system.

Total area of the separated system is more than PV/T system 62.5%. Initial cost of separated system is little lower. This causes the better economics than the PV/T system but not much. The larger area is a major disadvantage of the separated system.

Assume the initial cost of electricity generated by PV/T system is the same as the PV system. The cost of electricity generated by PV/T system should be less than PV system because water flow though PV/T collector should increase PV efficiency. But, PV efficiency in this PV/T system does not increase because a glass cover causes higher cell temperature. However, the cost of thermal energy generated by PV/T system is lower than SWH system because the added cost for thermal energy generating of PV/T system is lower than initial cost of SWH system about 19.5% but thermal energy delivered is lower only 3.2%.

Due to the price of fuel in 2007, the PV/T system causes the best benefit in case of replacing electricity. If conventional fuel is diesel oil, it causes positive net present value but not much also internal rate of return, and pay back period almost equal to its life cycle. In case of fuel oil and LPG, the bad economics is occurred due to low price in fuel oil, and high heating value and efficiency in LPG.

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