Enhancement of Performance of Photo Voltaic Cell using Methanol

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Abstract— A solar photo voltaic thermal (PV/T) system is considered, PV/T is a system of integrating photovoltaic cell and thermal collector in a single equipment. There is a drop in electrical efficiency with respect to increasing in temperature of photovoltaic (PV) module. There will be 0.5% efficiency drop for every 1°c raise after reaching the maximum allowable temperature. In order to overcome this drop in efficiency the temperature of PV panel will be reduced by cooling the PV panel with help of working fluid (water + methanol). A PV module of 0.35m x 0.15m is considered for investigation. The absorber collecting plate is made up of pure copper. The copper tube of cross-section of circular tube with 10mm and 12mm of inner and outer diameter respectively is considered. The length of tube is 3.85.a theoretical model was developed and solved to obtain the overall heat gain and over all combined efficiency of PV module by energy balance equation. The results obtained from theoretical module shows that over all heat gain and maximum thermal efficiency obtained by using (water + methanol) is more than conventional based fluid. The maximum thermal efficiency and maximum electrical efficiency was obtained.

Key words: Methanol, Photo Voltaic Cell

I. INTRODUCTION

The current energy scenario is gradually shifting towards various source of renewable energy due to continuous increasing pressure on energy demand, without degradation of environment through green house gas emission. Hence renewable technologies are considered as clean energy source with optimal use of these resources minimize environmental impact and produce minimum secondary waste. Solar energy is the basis of all renewable energies at present 14% of world's energy demand is meet by solar energy and its future potential is bodacious. Major two application of solar energy are i) solar thermal system in which solar energy is converted into thermal energy, ii) solar PV system in which solar energy gets converted into electrical energy. Power generation by photovoltaic cells is one of most important and hopeful renewable energy technologies. The conversion efficiency of a PV module is only 4-17% [3] of incoming solar radiation. It depends on material type, orientation and working condition of solar cell, more than 60% of incoming solar radiation will be dissipated as heat. Due to this dissipated heat energy will increase the working temperature of solar cell. The main obstacle occur during operation of PV panel is overheating due to excessive solar radiation and high ambient temperature. Over heating of PV panel will make the efficiency to drop drastically [1]. The ideal PV-characteristics of a solar cell of temperature range from 0°C - 75°C is shown in fig [1] which is shown in [1]

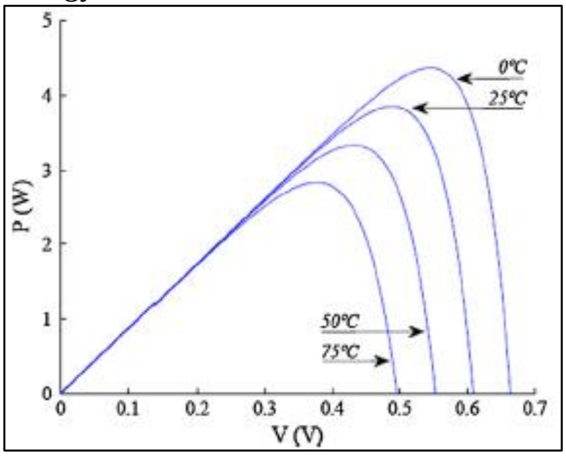

Fig. 1:

which is adopted from Rodri-gues et al [2]. The PV- characteristics is the relation between electrical power output of solar cell and output voltage V, when solar irradiance E and module temperature T_m are kept constant. If any two constants were changed then whole characteristics changes. When cell temperature increases the maximum power output from solar cell decreases as can been shown in fig [1]. Increase in temperature will also leads to thermal degradation of module if this thermal stress prolonged for a long period. For crystalline silicon solar all based on thumb rule the conversion efficiency drops by 0.5% for every 1°C rise in working temperature [3]. Hence we need an effective cooling system to achieve higher heat transfer rate from PV module.

The cooling system could be done by using air / water fluid stream; we can reuse the heat extracted by the coolant. This paved way for PV/T collector is a module in which PV will not only produce electricity but also serve as a heat absorber. By this method both heat and electric power are produced simultaneously various different types of design for thermal absorber were developed for performance of flat plate solar PV/T collector [4]. From this various design tube and sheet design with straight flow is the simplest and easiest construction for manufacturing. The overall analysis of energy and energy on hybrid micro channel solar cell thermal tiles is presented [5]. This detailed study showed that series connection was helpful in CO_2 mitigation and earning carbon credits. Factors like solar irradiation, ambient temperature, wind speed, operating temperature of cell and tedlar will influence the overall efficiency of solar hybrid PV/T system [6].

Agarwal et al [7] carried overall analysis of exergy and energy with four different configuration of hybrid PV/T system. The flow configuration with two column of 18 module each having 36 PV/T tiles in module as working fluid has grown in technologies in recent years. Many researchers found that water will give the better cooling than air and receiving facility also promote water based cooling than air based. Various researchers have used various other conventional coolants and additive to improve the heat transfer rate of water. Karami et al [8] have conducted experiments to test the cooling performance of PV cell using water and water based nano fluid. The result showed that water based nano fluid gives greater efficiency than water but it cost is very high and requires separate maintenance procedure.

In this paper a thermal modeling of solar PV/T with (water + methanol) of 44% volume concentration is considered a theoretical model is solved and the flat plate collector design with straight flow having circular cross section is considered.

II. System Specification

A theoretical model was developed based on assuming a thermal modeling which consist of a hybrid PV/T. The hybrid PV/T of [0.35m x 0.15m] length and breadth respectively is considered. The PV/T first comprise a PV module in which a layer of solar cell is sand-witched in between upper layer of glass and lower tedlar layer, underneath the tedlar circular tube is assumed to avoid heat loss to atmosphere. The absorber plate does a dual role where it plays an important role of cooling the PV module and collecting thermal energy in form of hot water. This increases the efficiency of PV module.

The geometric dimensions of circular tubes were fixed based on width to diameter technique. Based on that a design of 11 tubes of with 10mm as inner diameter and 12mm as outer diameter, width between tube is assumed 14mm. the total length of tube is 3.85m

III. Thermal Modeling

A. Assumptions Made

The following assumptions were made in this thermal modeling of PV/T system.

- Mode of heat transfer is one dimensional.
- Compared with heat capacity of working fluid (water + methanol) heat capacity of solar cell, tedlar and insulation were neglected.
- Hybrid solar PV/T was assumed to be in horizontal plane.
- Cell temperature and wall temperature remains constant.
- Along thickness of solar cell there is no temperature gradient.
- Specific heat of fluid remains constant when cell temperature changes.
- Ohmic losses are neglected.
- The flow is laminar and uniformly forced circulation with fully developed regime.
- Inlet fluid temperature is 27°C.
- Mass flow rate is 0.01kg/s.
- Wind velocity is 1 Knots.

B. Design Parameter for Modeling

1) Inlet diameter of the tube = 0.01m.
2) Length of the overall tube = 3.85m.
3) Transmissivity of glass material = 0.95
4) Glass thickness = 3mm.
5) Absorptivity of tedlar = 0.5m.
6) Cell's packing factor = 0.4
7) Absorptivity of cell = 0.75(0.74 – 0.78).
8) Glass's thermal conductivity = 1.1W/mK
9) Tedlar's thermal conductivity = 0.333W/mK
10) Tedlar thickness = 1mm
11) Heat transfer co-efficient of tedlar = 10.3W/m^{2}K
12) Thermal conductivity of the absorber plate = 401W/mK
13) Absorber plate thickness = 1mm
14) Insulation thickness = 0.02m
15) Thermal conductivity of insulation material = 0.035W/mK
16) Heat transfer co-efficient of insulated material = 5.8W/m^{2}K

C. Energy Balance Equations for PV/T System

The modified energy balance equation of various components for PV/T system are considered as in Rajoria et al [10].

1) Efficiency of the Solar Cell of the PV Module

Energy balance equation of PV/T system can be written as [solar energy available on PV/T per unit time] = overall heat loss from top of the PV/T system to atmosphere per unit time] + [overall heat transfer from PV panel to back surface per unit time] + [electrical energy produced per unit time].

$$[\tau_g\alpha_c\beta_c + \alpha_T (1- \beta_c)]\, I(t)\, bdx = [\, U_{lc,a} (T_c - T_a) + U_T(T_c - T_{bs})]bdx + nc\tau_g\alpha_c\beta_c\, I(t)\, bdx \qquad (1)$$

Where τ_g is transmissivity of the glass,α_c is Absorptivity of the glass,β_c – Packing factor,B is width of the tube.

From the equation (1) solar cell temperature could be obtained.

$$T_c = \frac{\alpha_{eff}\, I (t) + U_{lc,a}T_a + U_T T_{bs}}{U_{lc,a} + U_T} \qquad (2)$$

Where T_c is temperature of cell,T_{bs} is temperature of tedlar,T_a is temperature of atmosphere,I (t) is solar irradiation,U is overall heat transfer co-efficient.

The expression of temperature dependent electrical efficiency is taken from Evans et al [9]

$$\eta_c = \eta_o[1 - \beta_o(T_c - T_a)] \qquad (3)$$

Where β_o is 0.0045,η_o is 0.12.

2) Temperature at Back Surface of Tedlar Sheet

[overall heat transfer rate from PV panel to back surface of tedlar] = [heat transfer rate from back surface of tedlar to flowing fluid]

$$U_T (T_c - T_{bs})\, bdx = h_T(T_{bs} - T_f)\, bdx \qquad (4)$$

Where h_T is heat transfer co-efficient,T_f is temperature of working fluid.

Sub T_c in equation (4)

$$T_{bs} = \frac{\alpha_{eff}\, I (t) + U_{tT}T_a + h_T T_f}{U_{tT} + h_T} \qquad (5)$$

3) Temperature of Working Fluid Flowing Below Absorber Plate

[Heat transfer rate of the flowing fluid] + [overall transfer of working fluid to atmosphere] = [heat transfer rate from back surface of absorber plate to working fluid]

$$m_f C_f(dT_f/dx)dx + U_b(T_f - T_a)bdx = h_T F'(T_{bs} - T_f)bdx \quad (6)$$

Where F' is corrected fin efficiency, m_f is mass flow rate, C_f is heat transfer co-efficient of working fluid

Sub equation (5) in (6) we get

$$(dT_f/dx) + (F'bU_L / m_fC_f)\, T_f = [\, PF\ \ \alpha_{eff}\, I\ (t) + U_LT_a]\ (F'b/m_fC_f) \qquad (7)$$

Where PF is Penalty Factor.
Where equation (7) can be written as

$$(dT_f/dx) + a\, T_f = f(x) \quad (8)$$

Where T_f is the fluid temperature

a = $(F'bU_L / m_fC_f)$

f(x) = $[\,PF\ \alpha_{eff}\, I(t) + U_LT_a]\,(F'b/m_fC_f)$

The solution for equation (8) is obtained by integrating and applying initial conditions at x = 0, $T_f = T_{fi}$; x = L, $T_f = T_{fo}$

$$T_f = [f(x)/a]\,\{1-e^{(-ax)}\} + T_{fi}\, e^{(-ax)} \quad (9)$$

$$T_{fo} = [f(x)/a]\,\{1-e^{(-aL)}\} + T_{fi}\, e^{(-aL)} \quad (10)$$

D. Useful Heat Gain

The expression for useful heat gain of the PVT module is given as

$$Q_{u,N} = m_fC_f\,(T_{fo} - T_{fi}) \quad (11)$$

Sub equation 10 in 11 we get

$$Q_{u,N} = m_fC_f\,([f(x)/a]\,\{1-e^{(-aL)}\} + T_{fi}\, e^{(-aL)} - T_{fi}) \quad (12)$$

Or

$$Q_{u,N} = F_RbLN[PF\ \alpha_{eff}\, I(t) - u_L\,(T_{fi} - T_a) \quad (13)$$

Where F_R is heat removal factor

E. Instantaneous Thermal Efficiency

Equation 13 can be used to get the expression for instantaneous thermal efficiency

$$\eta_i = F_R\,[PF\ \alpha_{eff} - \{u_L\,(T_{fi} - T_a)/I(t)\}] \quad (14)$$

F. Temperature Dependent Electrical Efficiency

$$\eta_c = 0.12[1 - 0.0045(T_c - T_a)] \quad (15)$$

Where η_o is the efficiency at standard condition, I (t) is 1000 W/m^2, T_c is 25°C.

G. The Themo Physical Properties of Coolant (Methanol/Water)

Physical properties are calculated by using mixture rule. Properties have been taken from table.

Molar mass	32.0419 g/mol
Phase	Liquid (at STP)
Melting point	-98°C
Boiling point	64.7°C
Solubility in water	Miscible
Density	0.791 g/cm^3

Table 1:

- Density ρ_{nf} = $(1-Ø)\,\rho_f + Ø\rho_p$
  Where Ø is percentage of methanol present, ρ_f and ρ_p are density of water and methanol
- Specific heat = $[(1-Ø)\,\rho_fC_f + Ø\rho_pC_p] / \rho_{nf}$
- Dynamic viscosity = $5.44 \times 10^{-4}\ Ns/m^2$
- Thermal conductivity = 0.4 W/mK
- Calculation of heat transfer co-efficient

$$Nu = 0.4328\,(1+11.285 \times Ø^{0.754} \times Pe^{0.218})\, Re^{0.333} \times Pr^{0.4} \quad (i)$$

Mass flow rate m_f = ρAV

Reynold's number (Re) = $\rho VD / \mu$ (ii)

Prandtyl's number (Pr)= $\mu\, C_{pf} / K_{pf}$ (iii)

Peclet number (Pe) = Re x Pr (iv)

Sub (iv). (iii), (ii) in (i) we get nusselt number from which heat transfer co-efficient could be calculated

h_t = Nu K / D.

IV. Result and Discussions

Thus by using methanol + water as the working medium we have obtained increase in thermal efficiency and electrical efficiency.

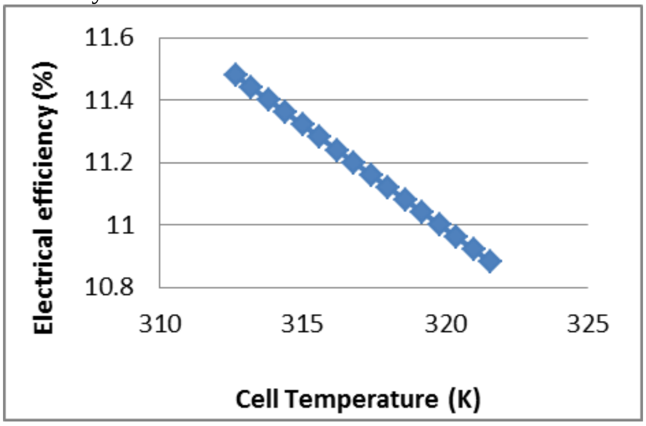

Fig. 2:

The overall efficiency of 46.27% is obtained by using PV/T system with combination of methanol and water. 40% addition of methanol with water is chosen as optimum concentration.

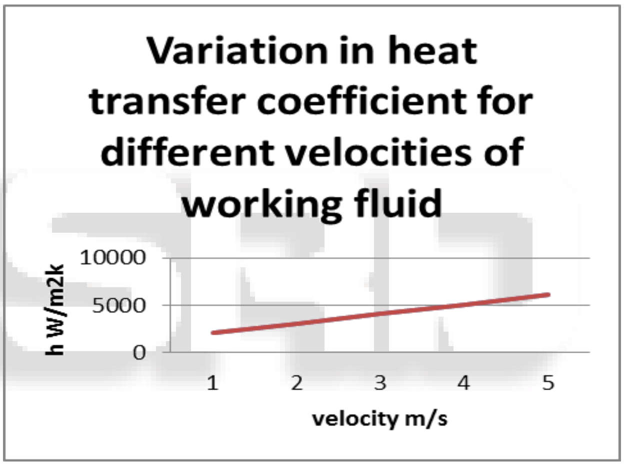

Fig. 3: Variation in heat transfer coefficient for different velocities of working fluid

The efficiency and other properties has been calculated for a sample value of mass flow rate at 0.01 kg/s. Variation of heat transfer co-efficient with different velocity is shown in table 2.

V. Conclusion

In this thesis a theoretical model was developed for PV/T system considering energy balance equations from various literatures. The various properties like thermal efficiency, electrical efficiency, cell temperatures and useful heat gain are found for a sample data by solving energy balance equations. From table 1 we could conclude that when increase in cell temperature there is decrease in electrical efficiency.

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