Hybrid Photovoltaic Solar Thermal Collector System

M. Mahesh Babu [1,] A. Rama Krishna[2], J. Naga Raju[3]
[1.] BVC Engineering College
[2.] Professor, mechanical engineering department, BVC engineering college, JNTU Kakinada, India
[3.] Asst professor, mechanical engineering department, Malla Reddy College of engineering, JNTU Hyderabad, India

***Abstract*— The hybrid photovoltaic/thermal (PV/T) collector is an integration of single-crystalline silicon cells into a solar thermal collector. The product is able to generate electricity and hot water simultaneously.**

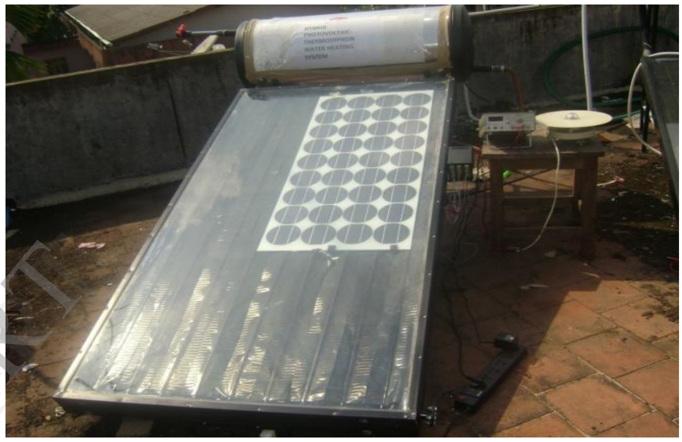
The solar radiation increases the temperature of PV modules, resulting in a drop of their electrical efficiency. By proper circulation of a fluid with low inlet temperature, heat is extracted from the PV modules keeping the electrical efficiency at satisfactory values. The extracted thermal energy can be used in several ways, increasing the total energy output of the system. Hybrid PV/T systems can be applied mainly in buildings for the production of electricity and hot water and are suitable for PV applications under high values of solar radiation and ambient temperature.

The results showed that PV cooling can increase the electrical efficiency of PV modules by 2 to 4% and thermal efficiency by 4 to 6% there by, increasing the total efficiency of the systems. Improvement of the system performance can be achieved by the use of an additional glazing to increase thermal output, a booster diffuse reflector to increase electrical and thermal output, or both, giving flexibility in system design.

I. INTRODUCTION

A solar thermal collector is a solar collector specifically intended to collect heat: that is, to absorb sunlight to provide heat. Although the term may be applied to simple solar hot water panels, it is usually used to denote more complex installations. There are various types of thermal collectors, such as solar parabolic, solar trough and solar towers. These type of collectors are generally used in solar power plants where solar heat is used to generate electricity by heating water to produce steam which drives a turbine connected to an electrical generator. More than 80% of the solar radiation falling on photovoltaic (PV) cells is not converted to electricity, but either reflected or converted to thermal energy.This leads to an increase in the PV cell's working temperature and consequently, a drop of electricity conversion efficiency, of about 3–6% loss per ^{o}C. In view of this, hybrid photovoltaic and thermal (PV/T) collectors are introduced to simultaneously generate electricity and thermal power. The hybrid photovoltaic/thermal (PV/T) collector is an integration of single-crystalline silicon cell into a solar thermal collector.The PVT system is able to generate electricity and hot water simultaneously.

II. EXPERIMENTAL SET UP OF THE HYBRID PVT COLLECTOR



A. Constituent layers of the hybrid PVT collector

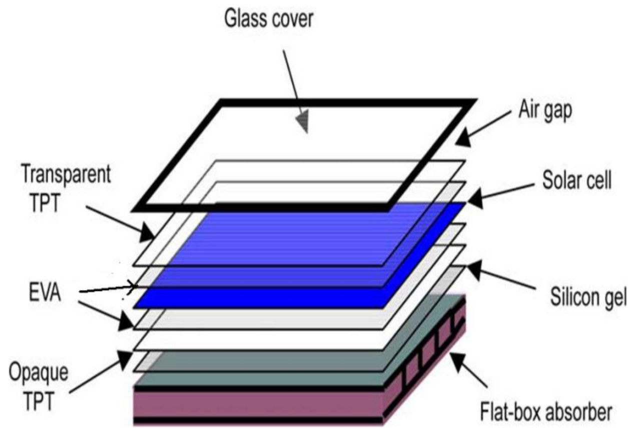
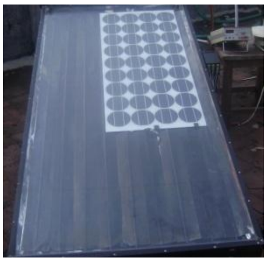


Fig: layers of PVT collector

B. polycrystalline silicon cell

Total No. of units (36),
Area (0.67sq.m),
Emissivity (0.8),
Cell conversion efficiency (14.5%),

C. Solar collector



Absorber material (Cu.)
Absorber type (Flat box)
Absorber module size (1.8 x 0.8 x 0.02 m^3)
Front glazing thickness (4mm)
Total effective area (2 m^2)
Thermal insulation thickness (10 mm)

D. water tank:

Specifications:
Type: cylindrical horizontal
Length (1.2 m)
Diameter (0.3 m)
Water-storage capacity (100 liters)
Thermal insulation thickness (30 mm)

E. Storage battery

Rated voltage (12 V)
No. of Units (4)

F. Converter

Rated input-voltage (48 V)
Rated output-voltage (220 V)
Maximum output-power (1000 W)

III. DESIGN OF THERMOSYPHON COOLING SYSTEM FOR PHOTOVOLTAIC CELLS

Cooling of photovoltaic cells is one of the main concerns when designing concentrating photovoltaic systems. Cells may experience both short-term (efficiency loss) and long-term (irreversible damage) degradation due to excess temperatures. Design considerations for cooling systems include low and uniform cell temperatures, minimal power consumption by the system.

A. Proposed Cooling System

We proposed a water cooling system for the following reasons

- There is a substantial temperature rise along the cells due to the low heat capacity of air.
- The coolant liquid is water is anti-corrosive and can be used to the optical concentration.
- Specific heat capacity of water is high so that it can absorb the heat from any surface.
- Low cost investment and water is easily available and can be served as thermoelectric system.

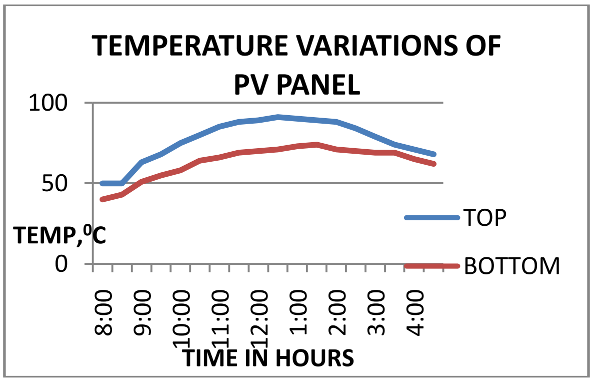
IV. EXPERIMENT PROCEDURE

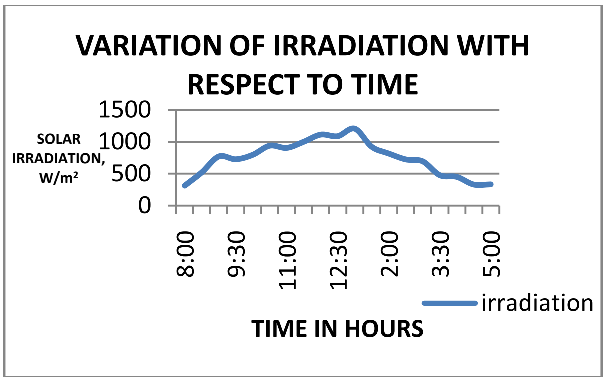
1. Remove water from the tank by opening drain cork.
2. Refill the water by opening storage tank valve.
3. Connect all sensors to micro controller.
4. For every 30 minutes note down following readings
   I. Inlet water temperature
   II. Out let water temperature
   III. Solar radiation
   IV. Voltage from panel
   V. Current from panel

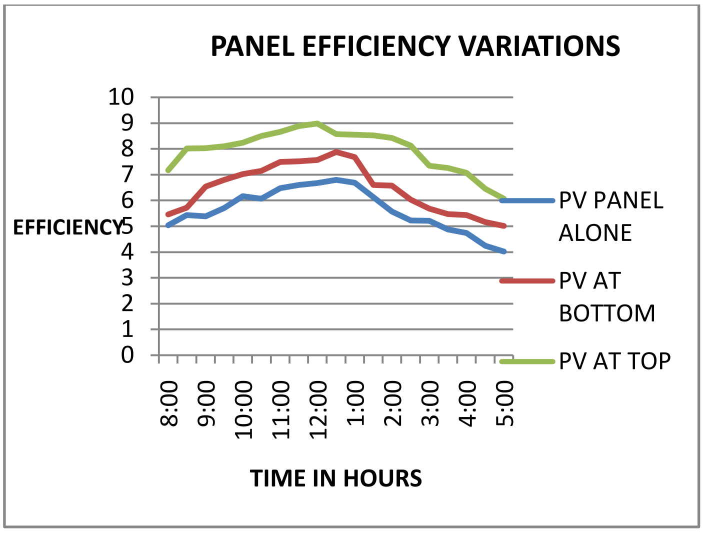
V. CALCULATIONS

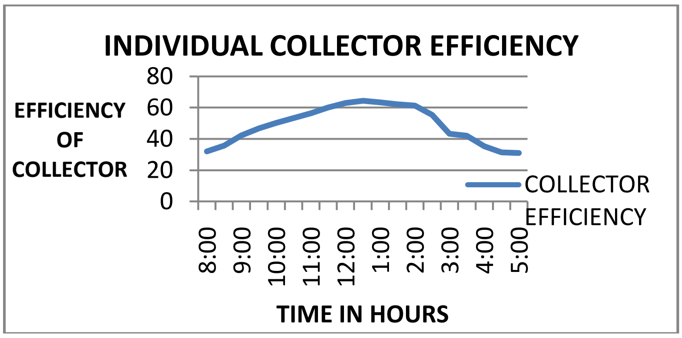
Energy input to solar collector = $H\ A_c$
Energy output from solar collector = $M\ (T_o – T_i)$
Energy input to PV panel = $H\ A_p$
Power output from solar panel = $V\ I$
Thermal efficiency, $ή_T = M\ C_p\ (T_o – T_i) / H\ A_c$
Electrical efficiency, $ή_E = (V\ I) / (H\ A_p)$
Total efficiency, $ή_O = ή_T + ή_E$
Where
$A_{c:}$ Collector area (m^2)
$A_{p:}$ PV panel area (m^2)
H : Solar radiation (W/m^2)
M: Mass of water in water tank (kg/s)
T_i:Collector inlet water temperature(^oC)
T_o : Collector outlet water temperature(^oC)

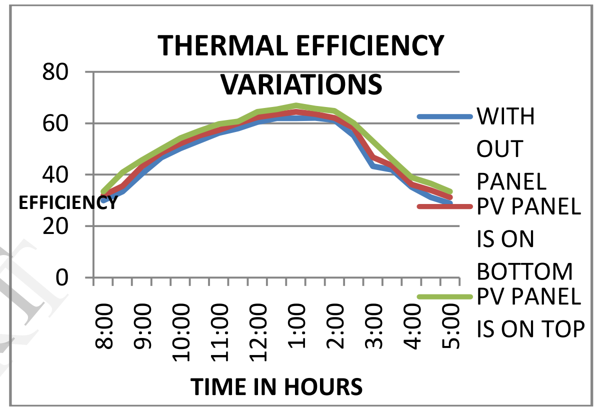
VI. GRAPHS

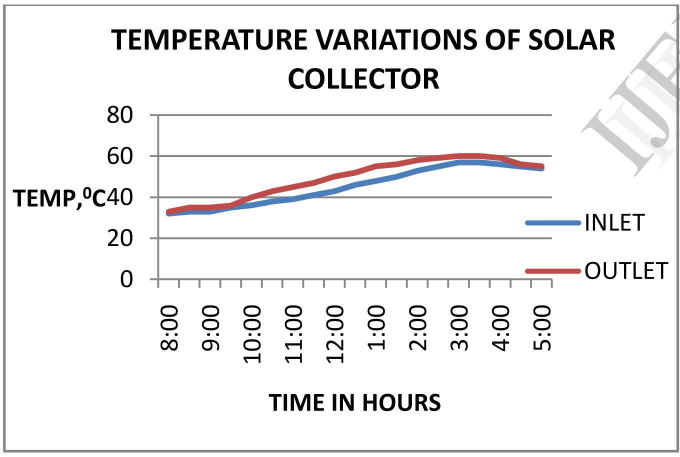












VII. RESULTS

Our proposed flat-box cu-alloy solar PV/T collector has many merits, as compared to the flat-box collectors, such as the large contact area to facilitate heat exchange between the absorber plate and the fluid, the uniform transverse temperature distribution across the collector width, and the flat metallic surface as a high-quality lamination between the PV cells and the absorber plate.

The PV/T water heating system was designed with natural circulation and experiments were conducted As the hot-water load per unit heat-collecting area exceeded 80 kg/ m2, the daily electrical efficiency was about 10.15%, the characteristic daily thermal efficiency exceeded 45%, the characteristic daily total efficiency was above 52% and the characteristic daily primary energy saving was up to 65%, for this system with a PV cell covering factor of 0.63 and front-glazing transmissivity of 0.83.

Because of the shared front glazing, back cover and fixed frame, this flat-box collector is able to achieve more energy yield and needs less investment per unit surface area than the conventional PV and solar thermal systems in parallel. When more and more solar systems are required to be installed in buildings, the PV/T application can be the solution for it maximizes the solar energy outputs from the very limited facade areas.

REFERENCES

[1]. Erzat Erdil, Mustafa Ilkan, Fuat Egelioglu, "An experimental study on ener generation with a photovoltaic (PV)solar thermal hybrid system", Article history: Received 26 December 2007 www.elsevier.com/locate/energy.

[2]. K.F. Fong , Z. Lin , A.L.S. Chan J. Ji, T.T. Chow, G. Pei, "Energy and exergy analysis of photovoltaic–thermal collector with and without glass cover" www.elsevier.com/locate/energy.

[3]. A.S. Joshi, A. Tiwari, G.N. Tiwari, I. Dincer, B.V. Reddy, "Performance evaluation of a hybrid photovoltaic thermal (PV/T) (glass-to-glass) system" www.elsevier.com/locate/ijts, Received 23 January 2008;

[4]. Niccolo Aste, Giancarlo Chiesa, Francesco Verri, "Design, development and performance monitoring of aphotovoltaic-thermal(PVT) air collector",Renewable Energy 33 (2008) 914–927.

[5]. Arif Hepbasli, "A key review on exergetic analysis and assessment of renewable energy resources for a sustainable future", Renewable and Sustainable Energy Reviews 12 (2008) 593–661.

[6]. Vivek Raman, G.N. Tiwari, "Life cycle cost analysis of HPVT air collector under different Indian climatic conditions",Energy Policy 36 (2008) 603-611.

[7]. B. Robles-Ocampoa, E. Ruı z-Vasquezb, H. Canseco-Sa nchezb, R.C. Cornejo- Mezac, G. Tra paga-Martı´ nezd, F.J. Garcı -Rodrigueza, J. Gonza lez- Hernandeze, Yu.V. Vorobievd, "Photovoltaic/thermal solar hybrid system with bifacial PV module and transparent plane collector", Solar Energy Materials & Solar Cells 91 (2007) 1966–1971.

[8]. G. Fraisse , C. Me ne zo, K. Johannes, "Energy performance of water hybrid PV/T collectors applied to combisystems of Direct Solar Floor type", Solar Energy 81 (2007)1426–1438.

[9]. Anand S. Joshi, Arvind Tiwari, "Energy and exergy efficiencies of a hybrid photovoltaic- thermal (PV/T) air collector, "Renewable Energy 32 (2007) 2223– 2241.

[10]. Y. Tripanagnostopoulo, "Aspects and improvements of hybrid photovoltaic/thermal solar energy systems", Solar Energy 81 (2007) 1117–1131.