Performance Improvement of PV Module by Using an Exhaust Fan. (May 2016)

Nikhil P. Chonde[1], *PG Scholar*, Asst.Prof A.R. Suryavanshi[2], *MechanicalEngineering Department (ZCOER)*
Dr.G. S. Tasgaonkar[3], *FormerPrincipal (ZCOER)*

***Abstract*—The low efficiency of the solar panels has always been the main concerns in the development and usage of solar Photovoltaic (PV) technology. With the increase in temperature of solar cell a linear decrease in solar cell voltage is observed [1]. The solar energy operated exhaust fan with ducting can be integrated to create a forced flow at the bottom of the PV panel below any heat absorbing material. Solar panels absorb heat which results in increase in surface temperature of solar panel, which can be termed proportional to solar radiation intensity resulting decrease in efficiency of PV panel. The integration of solar energy operated exhaust fan in solar PV system can cause the air flow at the bottom surface of panels effecting cooling to the panels and increasing its efficiency and enhancing the electrical output. This work includes experimental analysis of solar energy operated exhaust fan integrated with solar panels.**

***Index Terms:* PV module, efficiency of solar PV, temperature effect on efficiency, etc**

I. NOMENCLATURE

PV	Photovoltaic
Ao,Ai	Cross sectional area of outlet and inlet to air flow channel respectively (m^2)
A_p	Area of panel (m^2) $=L_1L_2$
A_r	Ratio of Ao to Ai
A_w	Area of wall (m^2)
C_d	Coefficient of discharge of air channel inlet(0.57)
C_{f1}	Specific heat of air (J/kg K)
h_c	Conductive heat transfer coefficient for glass (W/m^2 K)
h_g	Convective heat transfer coefficient between air channel and glass cover (W/m^2 K)
h_{rs}	Radiative heat transfer coefficient between air channel and wall (W/m^2 K)
h_{rwg}	Radiative heat transfer coefficient between glass cover and wall (W/m^2 K)
h_w	Convective heat transfer coefficient between air channel and inclined wall (W/m^2 K)
h_{wind}	Convective heat transfer coefficient due to wind over glass cover (W/m^2 K)
S	Incident solar radiation on inclined surface (W/m^2)
K_f	Thermal conductivity of air (W/mK)
K_{ins}	Thermal conductivity of wall insulation (W/mK)
m	Mass flow rate of air (kg/s)
q"	heat transfer of air stream (W/m^2)
Q	Ventilation rate (m^3/s)
T_f	Mean temperature of air in channel (K)
Tfi	Inlet air temperature of channel (K)
Tf	Temperature of air at outlet of channel (K)
T_{amb}	Room temperature in (K)
Ub	Overall heat transfer coefficient between inclined wall and room (W/m^2 K)
Ut	overall heat transfer coefficients from top of glass cover (W/m^2 K)
ν	Wind velocity (m/s)
Δ	Wins Thickness of insulation behind absorber (0.05 m)
σ	Steffan–Boltzmann constant
e_g	Emissivity of top of glass cover (0.85)
e_w	Emissivity of black absorber surface (0.85)
ϱi	Density of air at inlet (Kg/m^3)
ϱo	Density ofoutlet air (Kg/m^3)
g	Accelerations due to gravity ($9.81m/s^2$)
Isc	Short circuit current
Voc	Open circuit voltage
E_{go}	Zero temperature band gap of semiconductor
γ	Includes the dependencies on temperature
Vgo	Ground circuit voltage

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Nikhil P. Chonde[1] is with the M.E. student, ZCOER, Pune-411041 (e-mail: nikhil.chonde@gmail.com).

II. INTRODUCTION

The efficiency of solar cell is greatly affected by temperature of cell and we cannot exempt increase in cell temperature. But an external system which will reduce the surface temperature of solar panel can be air cooled or water cooled. Various experiments have been made to check the effect of temperature over the performance of the PV module. The changes in weather condition have a great impact on the performance of the PV module. So to increase the efficiency of the solar panel it is important to evaluate the parameters affecting the performance and carrying out the required modification to increase the efficiency of the PVmodule.

A. History of Solar Technology

160 years of photovoltaic technology: It is surprising for most people to know that solar technology actually dates back over 160 years. First discovered in 1839 but the advancement of the solar technology got accelerated in the 20th century. In 1839 while experimenting with metal electrodes and electrolyte,PhysicistAlexandre Edmond Becquerel in his experiments observed a physical phenomenon allowing conversion of light to electricity. An inventor Charles Fritts in 1883,mentioned the first solar cells made with selenium wafers. Edward Weston in 1888 received first US patent "solar cell". Nikola Tesla in 1901 received patent for "method of utilizing, and apparatus for the utilization of, radiant energy".

It wasn't until Albert Einstein wrote his paperin year 1905 on the photoelectric effect. Albert Einstein In 1905 publishes paper on “photoelectric effect” along with his theory of relativity. Robert Millikan in 1916 gained the experimental proof for Einstein’s theory on photoelectric effect. Einstein wins Nobel Prize for 1904 paper on photoelectric effect in 1922. Then commercial Solar Age Begins Bell Laboratories, while working on silicon semiconductors, discovered silicon had photoelectric properties and developed Si solar cells, achieving upto6% efficiency and early satellites were the primary use for these first solar cells and till date up to 16% for various applications [13].

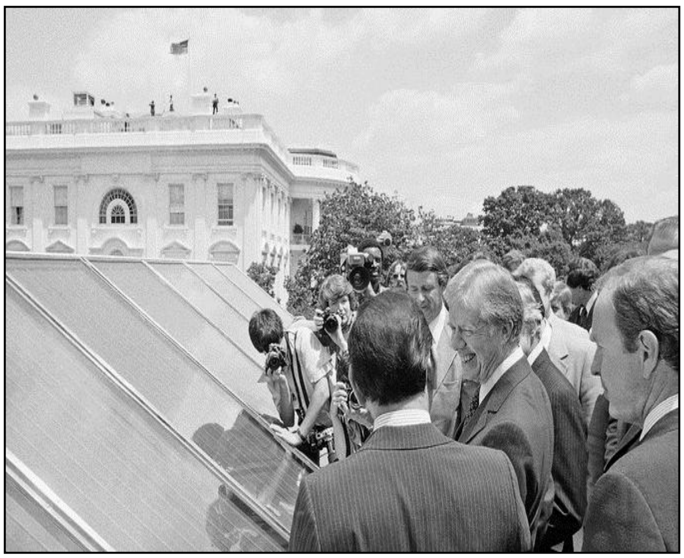

Figure 1 A Picture of PV panels installed in Germany in 1951

III. LITERATURE REVIEW

Shankar J. Yelpale, et al have worked on integration of solar chimney with PV panel for enhancing performance of solar PV system [1] and following were the ***observations***,

1. The system mentioned comprises of natural flow, in which the heat transfer coefficient is low.
2. The system comprises of chimney, for which cooling effect is observed on either side of chimney and is dependent position on position of the sun.
3. The Chimney shall also increase the shadow effect, and the land utilization is also reduced to an extent.

Mustafa Kayahas analyzed and presented thermal and electrical performance evaluation of PV/T hybrid collectors and observed an increase in electrical output with the decrease in temperature of panel[2].K.A. Moharram et al. have enhanced the performance of PV panels by water cooling and concluded that the cooling rate for the solar cells is 2°C/min[3]. J.K. Tonui et al.have improved performance of PV with natural air flow operation developed a mathematical module to evaluate the induced air flow rate and also simulate the system temperatures for natural air flow and found the thermal performance increases with increase in exit duct area[4].Amna A. Alzaabi et al. (2014) [4] have proposed a design that improved the electrical efficiency of PV panels.The collector pipes were covered by insulating material a rectangular shape of pipe was used to increase contact area between pipes and panel resulting in increase in the heat transfer rate [5].M. ArifHasan et al. examined photovoltaic thermal module concepts and their performance analysis for combined PV panel at top and thermal collector at bottom and with this system the extracted air can be utilized for domestic purpose [6].T.T. Chow reviewed photovoltaic/thermal hybrid solar technology and found that the low density of air causes the transfer volume to be significantly higher than in liquid[7] .H.A. Zondag reviewed Flat-plate PV-Thermal collectors and systems and found the heat transfer rate can be increased with application of pumps in PV/T water collectors[8].P.G. Charalambous et al. has reviewed water Photovoltaic thermal collectors and compared efficiencies which ranged from over 70% for a perfect collector and to less than 60%. Air PV/T collectors are generally less efficient than liquid ones, but it is very easy to design the tube with the sheet and also to manufacture which is only 2% less efficient [9].

IV. EFFECT OF TEMPERATURE OF PV PANEL OUTPUT

The efficiency of solar panel output is greatly affected by the increase in temperature. Mr. Martin A. Green, derived a relation between short circuit current (Isc) and open circuit voltage (Voc) is,[22]

$$\mathrm{Isc} = \mathrm{Io}(e^{q\mathrm{Voc}/kT} - 1)$$

Neglecting the small negative term, this can be written as

$$\mathrm{Isc} = AT^{\gamma} e^{\mathrm{Ego}/kT} e^{q\mathrm{Voc}/kT}$$

Where A is independent of temperature, E_{go} is zero temperature band gap of semiconductor with linear extrapolation making up the cell, and γ includes the dependencies on temperature, determining Io. Its value lies in the range 1 to 4. Differentiating gives, with

$$\mathrm{Vgo} = \frac{\mathrm{Ego}}{q}$$

$$\frac{d\mathrm{Isc}}{dT} = A\gamma T^{\gamma-1}\, e\text{^}(q(\mathrm{Voc} - \mathrm{Vgo})/kT) + AT\gamma\left(\frac{q}{kT}\right)\left[\frac{d\mathrm{Voc}}{dT} - \left(\mathrm{Voc} - \frac{\mathrm{Vog}}{T}\right)\right] e^{q(\mathrm{Voc}-\mathrm{Vgo})/kT}$$

Neglecting dIsc/dT in comparison with more significant terms results in the expression,

$$\frac{dVoc}{dT} = -\frac{\left[Vgo - Voc + \gamma\left(\frac{kt}{q}\right)\right]}{T}$$

This shows a linear decrease in Voc with increasing temperature. Now, subtractingvalues (Vgo~1.2 V, Voc~ 0.6 V,γ~3, T=300K) gives,

$$\frac{dVoc}{dT} = -\frac{[1.2 - 0.6 + 0.078]}{300}$$
$$= -2.3mV/°C$$

This conforms well to earlier experimental results. Hence the silicon, Voc decreases by about 0.4% per degree Celsius. The ideal fill factor is dependent on the value of Voc normalized with kT/q. Hence, the fill factor decreases with increase in panel temperature; adrastic variation is that of Voc. This results in decrease of power output and efficiency by 0.4 to 0.5 % per °C [16]

V. AIR VELOCITY AT THE OUTLET OF DUCT

The velocity in duct in terms of density ofair at inlet and outlet is calculated by [17].

$$Vi = \sqrt{2Dh(\rho_i - \rho_o)gh/fL\rho_i}$$

$$f = 0.25[log\frac{\frac{e}{D}}{3.7} + \frac{5.74}{Re^{0.9}}]^{-2}$$

VI. AIR FLOW AT BOTTOM SURFACE

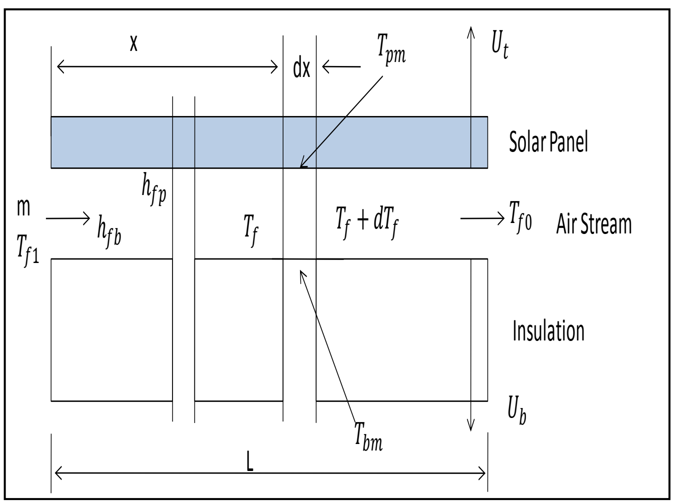

Figure 2 Air Flow at Bottom Surface of Solar Panel

The new system comprises of a solar panel attached with a heat absorbing material or an insulation plate, placed at the bottom side of the solar panel. This shall create a duct between the solar panel and the insulation plate. Through this duct an air stream shall flow, which shall carry the heat from the solar panel and thus, help to reduce the temperature of the panel.

The energy balance equation of solar panel [16]

$$SL_2dx = U_fL_2dx(T_{pm} - T_a) + h_{fp}L_2d*(T_{pm} - T_f) + \frac{6L_{2dx}}{\frac{1}{\varepsilon_p} + \frac{1}{\varepsilon_b} - 1} * (T^4{}_{pm} - T^4{}_{pm})$$

The energy balance equation for Air Stream [16]

$$mC_pdT_f = h_{fp}L_2d*(T_{pm} - T_f) + h_{fb}L_2d*(T_{pm} - T_f)$$

VII. PROPOSED PV SYSTEM WITH INTEGRATED EXHAUST AT BOTTOM SURFACE

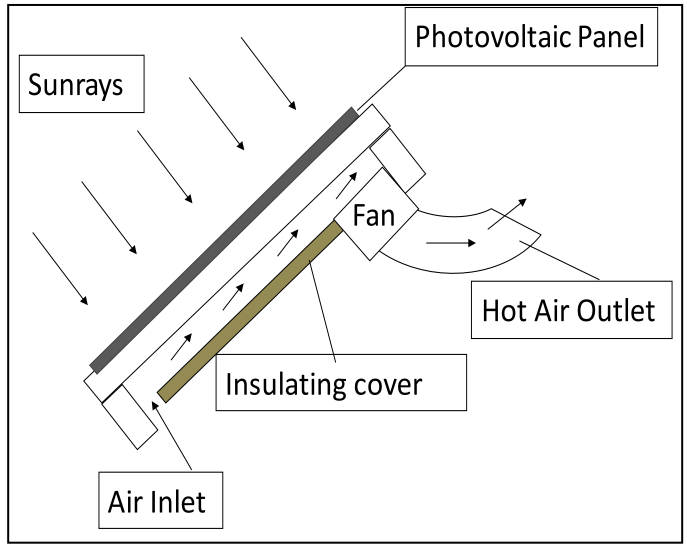

Figure 3 Proposed PV exhaust system

The proposedsystem comprises of a solar PV panel. The panel is placed south facing and the C channel at the bottom is attached with the insulating cover. An inlet is provided for the air to flow between insulating cover and the PV panel. Further at the upper side of insulating cover the a hole is to be drilled for the exit of the hot air. An exhaust fan is used to blow the hot air out of the system.

VIII. ACTUAL PHOTOGRAPHS OF THE SETUP

Figure 4 (A) Actual Setup photo

Figure 4 (B) Actual Setup photo

Figure 4 (C) Actual Setup photo

The PV panel is mounted on the fabricated frame south facing at Pune (18 ° 31' N and 73 ° 55' E) under a clear atmosphere in months of Jan'16 and Feb'16.

Table I
THE SPECIFICATION FOR THE SETUP

Parameter	Value
Angle of Slope	19°
Length	1500mm
Width	900mm
Duct Size	1500 * 900 * 40 mm
Panel Size	1500 * 900 mm
Area of Panel	135000 mm^2
Thickness of Insulation Plate	4mm
Material for Insulation	Wood Board
Fan Specification	12 V and 0.3 Amp
Testing period	10:00am to 5:30pm

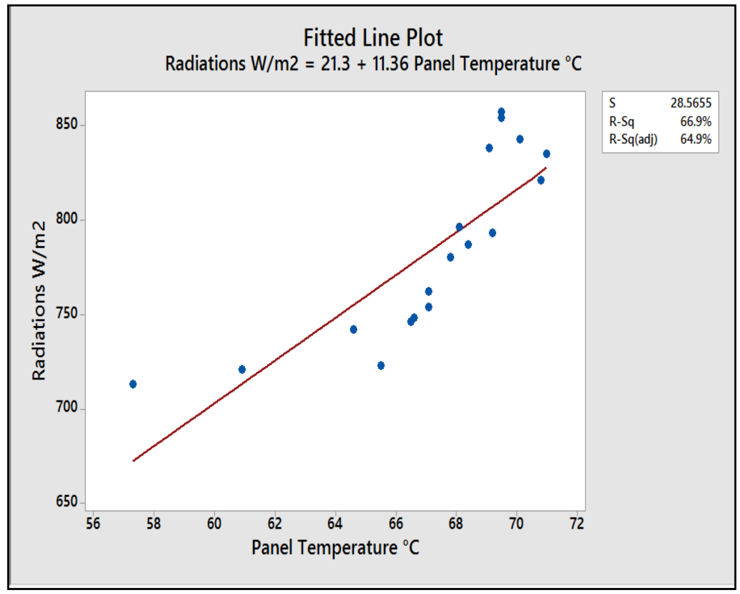

Figure 5 Radiation Vs Panel Temperature

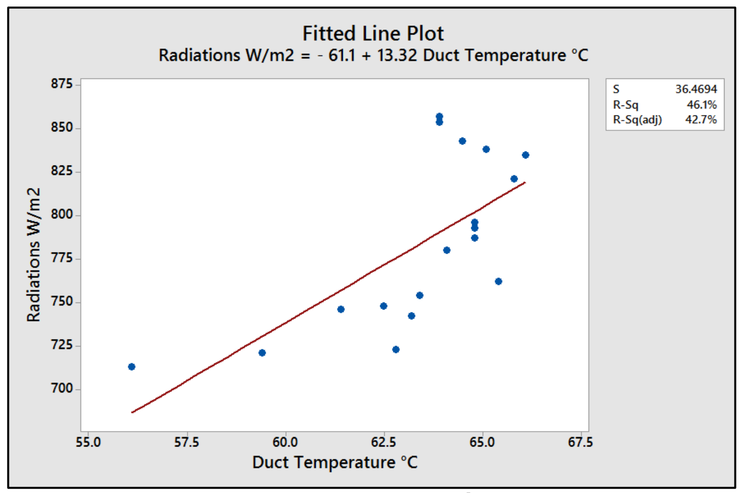

Figure 6 Duct Temperature Vs Radiations

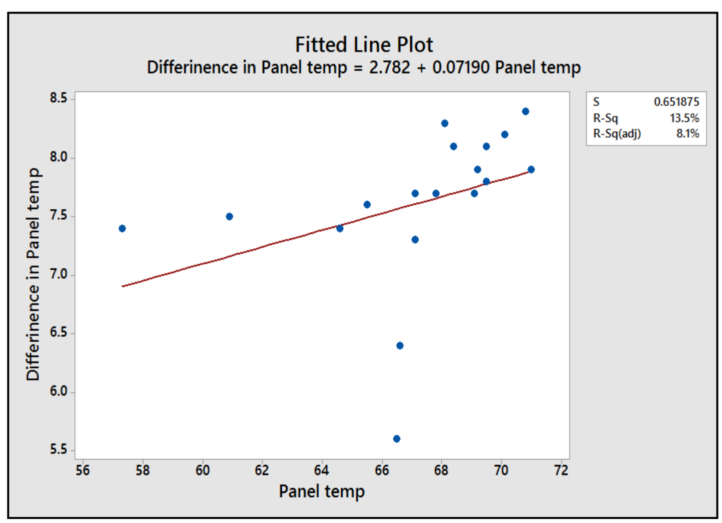

Figure 7 Panel Temperature Vs Difference in temperature

IX. CONCLUSION

The forced air draft created by exhaust fan is very effectively used to decrease the temperature of solar PV cell system. The observed temperature on upper surface is up to 72 ℃ and bottom surface is 65.2℃.Thus, increase the efficiency of the solar PV system. As the speed of fan increases with the intensity of solar rays the drop in temperature nearly 7.8 ° C is observed and theoretically which shall increase the efficiency by 3.99 % and also this hot air can be further utilised for domestic purpose.

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Nikhil Pradeep Chonde received the B.E. degree in Mechanical Engineeringfrom Pune University, Pune, India in 2011. He is currently Pursuing his Masters Degree in Computer Aided Design Manufacturing and Engineering CADME from ZCOER, SavitribaiPhule Pune University, Pune, India.

He holds an experience in product development and vendor development from FIAT India. His research interests are development of product and analysis in energy sector. He has worked with energy conservation development products since 2014. He also owns the knowledge of Lean Manufacturing techniques.