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Feasibility Investigations and Performance Analysis of Non Concentrated Solar Photovoltaic Thermal System for Nagpur

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***Abstract* - Non-concentrated solar photovoltaic thermal system act as a combined system, which will able to produce heat and electricity simultaneously. Both the electrical efficiency and heat gain of PV module depends linearly on the operating temperature. In this paper the theoretical estimation of efficiency of PV and heat gain from PV, through out the year is predicted. In the theoretical estimation it has been observed that the, maximum efficiency of PV can be improved by 2-3%, whereas average heat extraction is around 250-300 KW, from PV module. Position and performance analysis of PV at various tilt angles and at different conditions is estimated. The overall performance of PV can be improved by using appropriate concentrating system and advanced heat extraction methods.**

Keywords:- Photovoltaic/ Thermal system, solar energy.

1. INTRODUCTION

Solar energy is very large, inexhaustible source of energy and is most promisingly utilized in photovoltaic and in thermal systems for long. Many researchers are trying to develop combine system which facilitates the conversion of solar radiation into heat and electricity simultaneously. These systems could be best suited to the applications where the demand of heat and electricity is simultaneous. The literature review shows the existence of several such a systems, where heat is extracted from PV and used separately. The past work mainly includes the systems with single planned flat collector surfaces with concentrated or non-concentrated solar radiations. The flat plate collector is the most important types of solar collector because it is simple in design, has no moving parts and requires little maintenance. It can be used for a variety of applications in which temperature ranging from 40°C to about 150°C, with or without concentration. The PV/T system refers to a system which will able to give heat and electricity at a time, which extract heat from the panel with using heat transfer fluids, usually water and air is most promisingly used. One of the main reason behind use of PV/T is that having higher efficiency than individual PV and thermal collector system, in addition shortened payback period of the system make more reliable in use. Here we use Nagpur city (Maharashtra) as location site, having latitude: 21°09' N, longitude: 79° 09' E.

2. METHODOLOGY

Solar cell is an optoelectronic device which can directly converts solar energy into electric energy. The study of the behaviour of solar cell in the terrestrial application is very important as, they are exposed to temperature ranging from 15°C to 55°C and even higher temperature in concentrating systems. The performance of a solar cell is determined by the parameters such as short circuit current (I_{sc}), open circuit voltage (V_{oc}), fill factor (FF) and efficiency (η). The temperature variation affects these parameters so they will affect the performance of solar cells [1]. A typical PV module converts 6-20% of incident solar radiation into electricity, depending upon type of solar cell used and climatic conditions. Mostly mono crystalline silicon cell has better performance than poly crystalline silicon cells. The rest of the incident solar radiation which is in the form of undue heat is directly converted into heat, which significantly increases the temperature of PV module. This undue heat can be extracted by circulating cooling fluid such as air and water, above or beneath the PV module, using thermal collectors called photovoltaic thermal collectors.

A.Q.Jakhran and A.K.Othman, has stated many empirical models for estimation of photovoltaic module temperature by considering many factors. It will give more precise predictions during fluctuated operating conditions when the intensity of solar radiation and temperature will change with in a short period of time [2]. Zondag HA, stated Liquid type system, System performance was investigated with channels above and below PV module, channels below PV modules gives better efficiency [3]. Ghani Etal considered a PV/T collector of various design, geometric shape and operating characteristics and discussed the effect of non-uniform flow distribution on the thermal and electrical performance of their solar system [4].Wei He, Yang Zhang done the comparative experimental study on PV/T system under natural circulation of water, due to natural circulation there is increased in thermal efficiency by 20-25%, but it will adversely affect on electrical efficiency [5]. Mishra & Tiwari, considered two configurations in which the collector is partially and fully covered by PV module and compared their results with those of a conventional flat plate collector [6].Tooraj Yousefi, Studied the effect of Al2O3e-H2O nano fluid on the efficiency of flat-plate solar collectors for enhancement in heat transfer, For 0.2 wt% the increased efficiency was 28.3% [7]. K.A.Moharram, enhanced the performance of photovoltaic PV panels by water cooling, use of water spray technique & try to maintain constant temperature of PV module, improved efficiency reported [8]. In these couple of years, PV/T air and PV/T water system have been widely used and is investigated to increase system overall performance.

3. THEORETICAL PERFORMANCE ANALYSIS OF PV/T

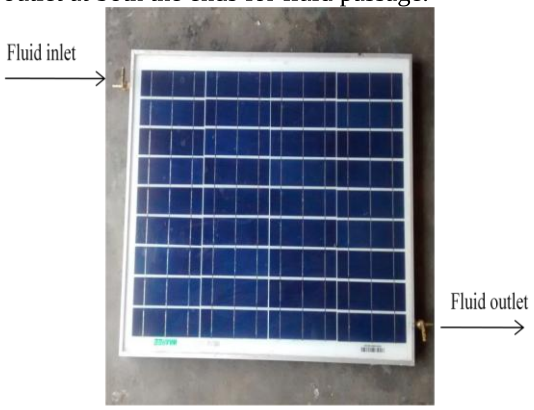
As shown in fig (1), the system consists of one mono crystalline PV module of 40 watt,

Pmax=40W, Vmpp=17.0 V, Impp=2.35 A, Isc=2.54 A, Voc=21.0V

All these values are measured at (STC 25 °C) standard temperature condition.

Dimension: 52cm× 67.5cm×3cm

Which is directly mounted on a stand, which is tilted to the ground at a specified angle known as β. Lower side of PV module is closed by a thin sheet of metal, having inlet and outlet at both the ends for fluid passage.



In this system there is no use of any concentrating system. Here whole system is inclined in such away that maximum incident of radiation is possible. In this system suitable cooling medium is used to extract heat from PV modules, which not only gives thermal output, but also helps to PV module at low temperature.

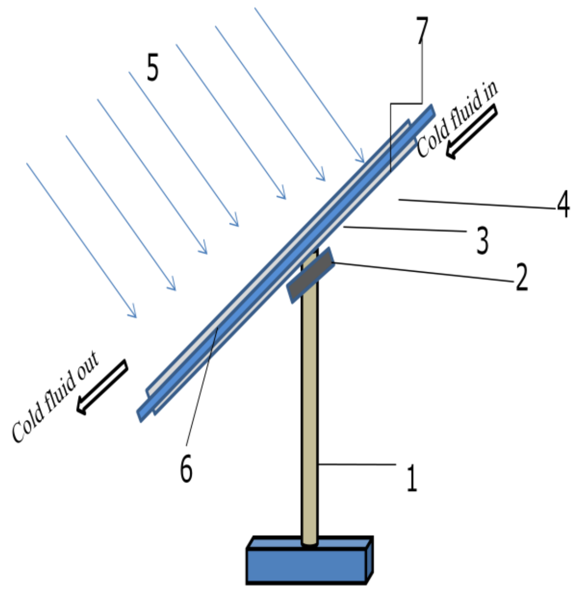


Fig. 1: proposed concentrated solar photovoltaic-thermal flat plate collector system.

(Legends: 1- supporting column, 2-angle changer, 3- fluid channel, 4- thermal collector, 5-incoming solar rays, 6- glass wool insulation, 7- PV module)

Following are few parameters which directly or indirectly affect the performance of PV/T.

a. Module Temperature

Photovoltaic module operating temperature is one of the most important parameters for the evaluation of long term performance of PV systems, as it modifies the power output and system efficiency. Its affect varies with characteristic of PV module encapsulating material, thermal absorption and dissipation properties, types of PV cells, installation, configuration, operating point of module and climatic conditions of locality such as solar irradiation level, ambient temperature and wind speed [1-9]. PV module performance or efficiency is usually inversely proportional to the operating cell temperature, as for mono crystalline silicon solar cells efficiency decreases by about 0.45% for every degree rise in temperature.Thus, in the noon conditions, where the ambient temperature is about 35°C, the module temperature will be about 55°C to 60°C. The higher temperature of module is due to the use of glass cover of the module, which traps the infrared radiations becoming green house effect and increases the module temperature.

b. Effect of Solar Irradiation

The term irradiance is described as the measure of power density of sunlight received at a location on the earth and is measured in watt per meter square.Whereas irradiation is the measure of density of sunlight. The power output of a solar PV module strongly depends on the solar irradiance falling on it. The power of a module decreases almost linearly with the decrease in intensity of solar radiation on PV. Unfortunately, the solar irradiation available throughout the day is not constant. As the solar insolation keeps on changing throughout the day similarly I-V and P-V characteristic varies. With the increasing solar irradiance both the open circuit voltage and the short circuit current increases and hence fluctuation in the maximum power point occurs.

c. I-V Characteristics

I-V Characteristics is a curve between current and voltage. The area under the I-V curve is the maximum power that a panel would produce operating at maximum current and maximum voltage. The area decreases with increase in solar cell voltage due to its increase in temperature. Due to fluctuation in environmental conditions, temperature changes and irradiance level the IV curve will change and thus maximum power point will also change [11].

d. Rating of PV Modules

The solar PV modules are rated in terms of their peak power (W_p) output. It is the most important parameters from user's point of view. The W_p is specified by the manufacture under the specified condition called standard test conditions (STC). Here we use W_s 40. The STC conditions do not occur for most of the time and locations. Therefore the performance of module is done by using standard operating conditions (SOC) and nominal operating conditions (NOC). Both of these use a different concept of temperature, called nominal operating cell temperature (NOCT) [10]. The NOCT is defined as the temperature reached by a cell in an open circuited module under the following conditions:

- Irradiation=800 W/m^2
- Ambient temperature=20 ºC
- Wind speed=1m/s

e. Fill Factor

The fill factor is denoted as *FF*, which helps in characterizing the non-linear electric nature of the solar cell. Fill factor is defined as the ratio of the maximum power from the solar cell to the product of V_{oc} and I_{sc}, and it gives an idea about the power that a cell produce with an optimum load under given conditions, $P=FF*V_{oc}*I_{sc}$. Fill factor is also an indicator of quality of cell. With FF approaching towards unity the quality of cell gets better [11].

e. Effect of Inlet Temperature and Mass Flow Rate

As the fluid inlet temperature increases, the temperature of the absorber tube surface also increases. As a result, losses due to reradiation and convection to the surrounding increase, resulting in a decrease in efficiency. An increase in the mass flow rate of the thermic fluid increases the value of the inside heat transfer coefficient h_f. Due to this, the collector efficiency and heat removal factor increases, this leads to increase in efficiency. With increasing value of mass flow rate, the efficiency curve goes on decreasing at the same time pressure drop increases. Therefore it is very important to select an optimum value of mass flow rate without unduly high pressure drop.

4. THEORETICAL ESTIMATION OF MODULE TEMPERATURE, HEAT EXTRACTED AND EFFICIENCY OF MODULE

For efficient performance analysis of PV/T system, it requires lowering the operating temperature of module but with high irradiance. The current system is a flat plate PV/T, as for maximum electrical output we have to keep module temperature as low as possible and for maximum thermal output, we have to extract more heat from PV module.

Therefore it is very necessary to find out temperature of module/ cell. Since the temperature of cell is very difficult to measure, because the cells are firmly enclosed for moisture protection. Therefore in most cases the back side temperature of PV module is commonly measured and assumed as cell temperature [12]. Besides back side temperature, some researcher uses the average value of the front and back surface temperature of PV module and it uses as the appropriate temperature of module.

$$T_{mod} = T_{amb} + \left(\frac{NOCT - 20}{0.8}\right) P_{in} \quad (1)$$

$$\eta_{electrical} = \eta_o\{1 - 0.0045(T_{cell} - 25^oC)\} \quad (2)$$

$$Q_{extracted} = \rho_m * V_m * Cp_m * \Delta T \quad (3)$$

$$\beta_{opt} = \tan^{-1}[\{\textstyle\sum_{i=1}^{12} \bar{H}_{bi} \tan|\phi - \delta_i|\}/\{\sum_{i=1}^{12} \bar{H}_{bi}\}] \quad (4)$$

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5. RESULT AND DISCUSSION

For the calculation of Irradiance, values are directly taken from NASA Surface meteorology and Solar Energy. With the help of this we are able to estimate predicted module temperature and maximum heat extraction. For ambient temperature data, we uses Weather statistics for Nagpur, Maharashtra (India)

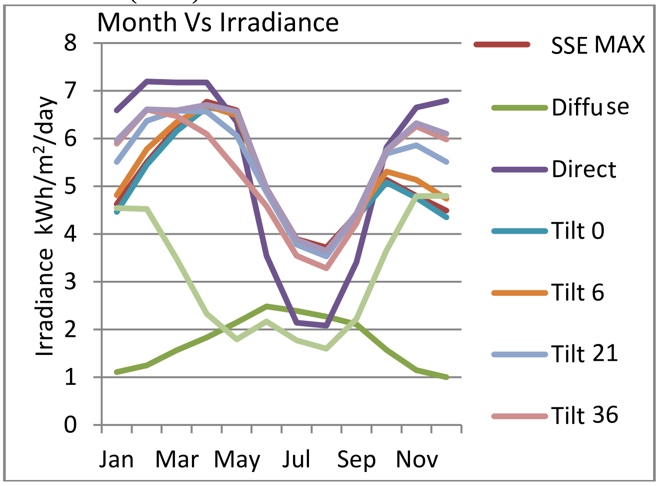

Fig: 2, Average irradiance Vs all months.

Shows the monthly average irradiance, in direct and diffuse condition. In additions average irradiance is also calculated by considering tilt angle ranging from 0 to 90 and optimum angle also.

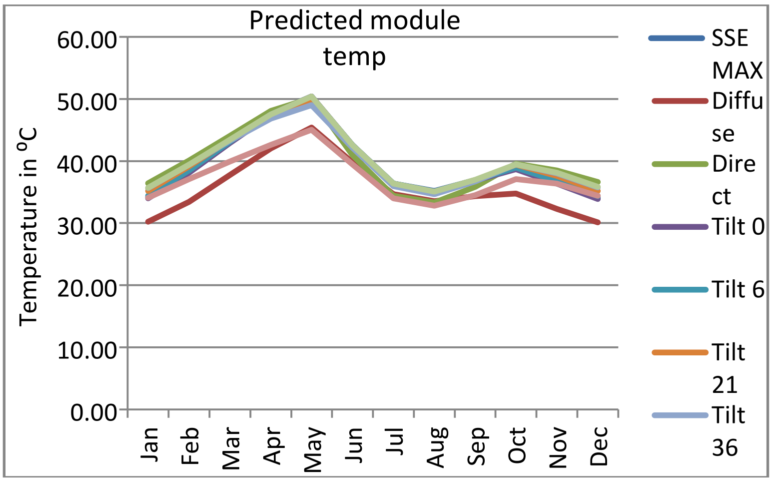

Fig: 3, Average predicted module temperature Vs all months.

Shows the monthly average predicted module temperature with respect to all months, at various conditions. This is useful to calculate the predicted electrical efficiency.

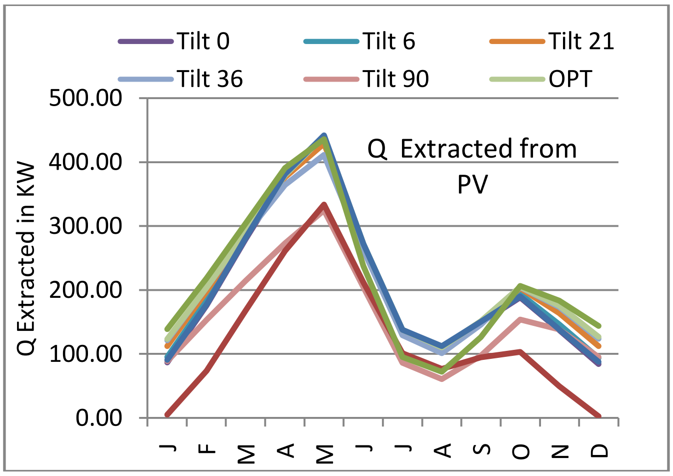

Fig: 4, Average heat extraction from module Vs all months.

Shows the monthly average predicted heat extraction from PV module with respect to all months, at various conditions. Here we just try to maintain the module temperature at 30°C and calculate the maximum heat extraction. This is useful to calculate the thermal efficiency of PV module.

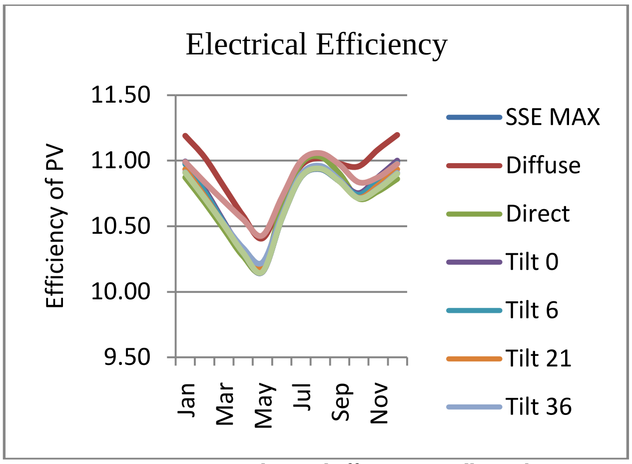

Fig: 5, Average electrical efficiency Vs all months.

The monthly average predicted Electrical efficiency with respect to all months, at a various conditions.

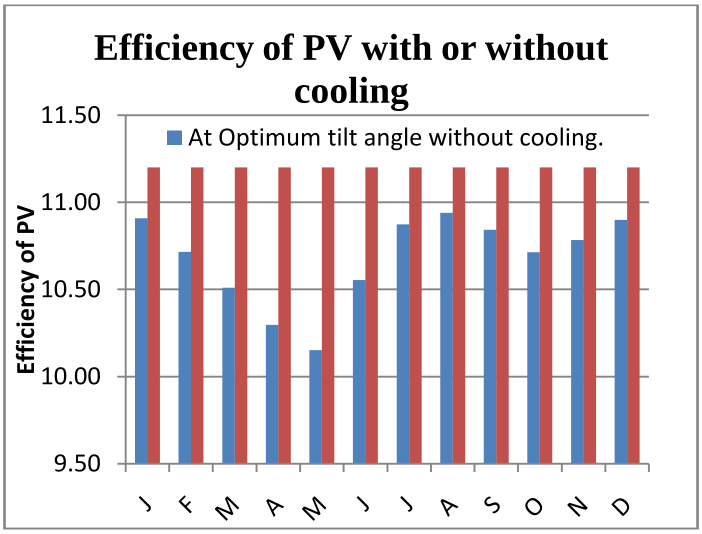

Fig: 6, Average efficiency of PV module with or without cooling.

Indicates the monthly average predicted Electrical efficiency with respect to all months, at optimum tilt angle with cooling and without cooling condition.

6. CONCLUSIONS

According to the estimated result, maximum irradiance is possible by Direct, Tilt at 36° and Optimum tilt angle radiations and minimum module temperature is possible by using Diffuse and Optimum tilt angle radiations. Whereas maximum heat extraction is possible by using Direct and Optimum tilt angle radiations, where as minimum for diffuse radiations and maximum electrical efficiency is possible by using Diffuse, tilt at 90° and at Optimum tilt angle radiations. As for better performance of PV/T module, we need minimum module temperature at maximum solar irradiance. This condition is satisfied at Optimum tilt angle. In addition by using appropriate concentrating system or reflectors, there is increase in overall performance of system [12-13]. For maximum thermal efficiency, use of suitable cooling medium will be desirable. Use of different channel design will also help to extract maximum heat from PV modules.

NOMENCLATURE

T_{mod}	temperature of module (^{0}C)
T_{amb}	ambient temperature (^{0}C)
NOCT	nominal operating cell temperature
NOC	nominal operating conditions
STC	standard test conditions
SOC	standard operating conditions
V_{oc}	open circuit voltage
I_{sc}	short circuit current
V_{mpp}	voltage at maximum power point
I_{mpp}	current at maximum power point
P_{max}	maximum power point
η	efficiency
P_{in}	radiation intensity in W/m,
β	inclination with ground
ρ_m	density of module (kg/m^3)
V_m	Volume of module (m^3)
Cp_m	Specific heat capacity of module (J /kg K)
h_f	heat transfer coefficient

REFERENCES

[1] Priyanka Singh, N.M.Ravindra, Temperature dependence of solar cell performance an analysis. Solar Energy Materials & Solar Cells 101(2012):36–45.

[2] A.Q. Jakhrani, A.K. Othman, Comparison of Solar Photovoltaic Module Temperature Models. World Applied Sciences Journal 14, 2011 (Special Issue of Food and Environment): 01-08.

[3] Zondag HA, De Vries DW, Van Helden WGJ, The yield of different combined PV thermal collector designs. Solar energy 74(2003): 253 69.

[4] Ghani, F., Duke, M., Carson, J.K., Effect of flow distribution on the photovoltaic performance of a building integrated photovoltaic/thermal (BIPV/T) collector. Solar Energy (2012) 86.

[5] Wei He, Yang Zhang, Jie Ji, Comparative experiment study on photovoltaic and thermal solar system under natural circulation of water. Applied Thermal Engineering 31 (2011) 3369-3376.

[6] R. K. Mishra and Arvind Tiwari, Study of Hybrid Photovoltaic Thermal (HPVT) Solar Water Heater at Constant Collection Temperature for Indian Climatic Conditions. Ashdin Publishing Journal of Fundamentals of Renewable Energy and Applications Vol. 2 (2012), Article ID R120310, 4 pages, doi:10.4303/jfrea/R120310. (SOLARIS 2012).

[7] Tooraj Yousefia, Farzad Veysia, Ehsan Shojaeizadeha, Sirus Zinadinib, An experimental investigation on the effect of Al2O3-H2O nano fluid on the efficiency of flat-plate solar collectors. Renewable Energy 39 (2012) 293-298.

[8] K.A. Moharram, M.S. Abd-Elhady, H.A. Kandil, H. El-Sherif, Enhancing the performance of photovoltaic panels by water cooling. Ain Shams Engineering Journal (2013) 4, 869–877.

[9] Swapnil Dubey, G.N. Tiwari, Thermal modelling of a combined system of photovoltaic thermal (PV/T) solar water heater. Solar Energy 82 (2008) 602–612.

[10] Solar Photovoltaic Fundamentals, Technologies and Applications (Second Edition), by Chetan Singh Solanki.

[11] Pradhan Arjyadhara, Ali S.M, Jena Chitralekha, Analysis of Solar PV cell Performance with Changing Irradiance and Temperature. International Journal Of Engineering And Computer Science ISSN: 2319-7242 Volume 2 Issue 1 Jan 2013 Page No. 214-220.

[12] Solar energy principles of thermal collections and storage (Third Edition), by S.P.Sukhatme, J.K.nayak.

[13] Swapnil Dubey, Jatin Narotam Sarvaiya, Bharath Seshadri, Temperature Dependent Photovoltaic (PV) Efficiency and Its Effect on PV Production in the World A Review. PV Asia Pacific Conference 2012, Energy Procedia 33 (2013) 311 – 321.