Hybrid PVT- A Novel Method For Improvement Of Solar Panel Efficiency

Prof.V.K. Thombare, Abhijeet J. Kumbhar, Vishal M. Devkate, Tushar R. Gurav, Aparna A. Gurav, Khalil R. Kotwal

***Abstract*— An alternative and cost effective solution to developing integrated PV system is to use hybrid photovoltaic thermal solar system .The temperature of PV modules increases due to absorbed solar radiation that is not converted into electricity, due to these increases the heat causing a decrease in their efficiency. In hybrid solar PV/T system the temperature of the of PV module can be reduced by using circulating of water through the collectors at the back side of the PV/T panel. In this paper we present the developing a new hybrid PV/T solar system. Hybrid PV/T system can provide electrical and thermal energy, thus achieving a higher energy conversion rate of the absorbed solar radiation. The main advantage of our combined PV/T solar system is to removing of heat from the PV panel, thus the decrease in temperature and increase in efficiency of system, also extend the lifetime of photovoltaic cells due to the removing of heat from PV part which is used to heat the water in the thermal part of the panel.**

Keywords- photovoltaic panel, Hybrid-photovoltaic thermal system, solar PV/T collector.

I. INTRODUCTION

Electricity and heat are the most important energy needs in the residential sector and the public and commercial services. Most of this energy is generated carriers from the center of conventional energy like coal and natural gas. The combination of photovoltaic systems and solar thermal producing both electricity and heat simultaneously.

A photovoltaic/thermal (PV/T) hybrid solar system is a combination of a photovoltaic (PV) and solar thermal system which produces both electricity and heat from one integrated system. By cooling the PV module with a working fluid, the electricity yield can be improved and the heat pick up by the fluid can be used for s water heating. Hence, the system becomes increasingly attractive in solar energy utilizations.

The functions of Photovoltaic Panels (PV) and thermal collectors can be integrated in a single device: the Photovoltaic-Thermal panel, or PV-T. With PV-Ts, the sunlight is converted into electricity and heat simultaneously. During the last 20 years the research into PV-T techniques and concepts has been widespread, but rather scattered. This reflects the number of possible PV-T concepts and the relevant research and development problems, deriving from the general goal to optimize both the electrical and the thermal efficiency of a device simultaneously. The aspects that can be optimized are, among others, the spectral characteristics of the PV cell, its solar absorption and the internal heat transfer between cells and heat-collecting system.

The efficiency of photovoltaic panel is 10% to 18% and that of thermal system is 60% to 80%, combination of both systems increases the overall efficiency of solar photovoltaic panel.

II. LITERATURE SURVEY

Various experimental and theoretical studies have been performed on PV/T hybrid systems since the 1970s. In order to optimize the energy output of the PV/T hybrid systems, there has been much research over the last 20 years. Authors' approaches to PV/T systems vary, but these systems are usually investigated in two main categories, as water hybrid and air-hybrid collectors. Some of these studies have been performed using water and dual water and air.

K. Touafek, M. Haddadi, and A. Malek [1] in his experimental results a new PVT hybrid collector is proposed on the basis of a new approach of design, which aim to increase the energy effectiveness of electric and thermal conversion with the lowest cost compared to the already existing conventional hybrid collector. One studied the distribution of the temperature theoretically in the different layers of this new hybrid collector and established the electric and thermal models of the collector. Then, one studied the new hybrid collector experimentally through the prototype made at the Unit of Applied Research in Renewable Energy. A total efficiency of 80% is achieved.

A. Khalifa, K. Touafek, I. Tabet [2] his result getting the efficiency of photovoltaic panel is sensitive to operating temperature and decreases when the temperature of the PV increases. Therefore, the PV/T hybrid systems are one means used to improve the electrical efficiency of the panel. In the study, the photovoltaic panel temperature significantly reduced by 15–20% due to the flow of water through the manifold to the rear of the PV panel (recalling that it is about 60C to 80C in the conventional photovoltaic solar panel).

PV/T hybrid collectors generate electrical energy beyond providing low temperature hot water. Thus, the total efficiency increases. Mark van Der Auweraer [3] his getting reviews on Photovoltaic and Thermal power integration. That the total theoretical efficiency of a PV/T collector that can be obtained is about 60–80%. Other test results stated that the thermal efficiency is about 50–70%. The obtained results are, however, the instantaneous efficiencies, which are measured or calculated under constant and low input temperature fluid flow conditions.

The solar energy conversion into electricity and heat with a single device called hybrid photovoltaic thermal (PV/T) collector is a good progress for future energy demand. H. M. Farghally, N. M. Ahmed, D. M. Atia, F. H. Fahmy [4] his paper presented a PV/T collector fed a small freezing factory in a remote area in Egypt. The factory needs the electricity and hot water for operation, so using PV/T collector is promising idea. A complete design of the vegetable freezing factory is represented in this study

C. Moscatiello [5] his concluded, PV-T features are very interesting when there is a demand for both thermal and electrical energy and there is a commitment to the use of renewable energies, even in presence of strict space and/or visual impact constraints. Although the high initial cost, when there are no particular constraints limiting the use of separate devices (available space, visual impact), the economic feasibility of such plants should be evaluated case by case and further technological and commercial development could guarantee higher revenues.

All those above clues lead the idea of drafting and designing this new PV/T water collector system which is economically viable. Such newly designed PV/T collector with transparent glass allows much more sunlight to fall on the pipe carrying cold water as a mean of which rate of heat transfer from the tube to that of transporting fluid has been improved. Thus results in the overall performance improvement in case PV/T hybrid water collectors.

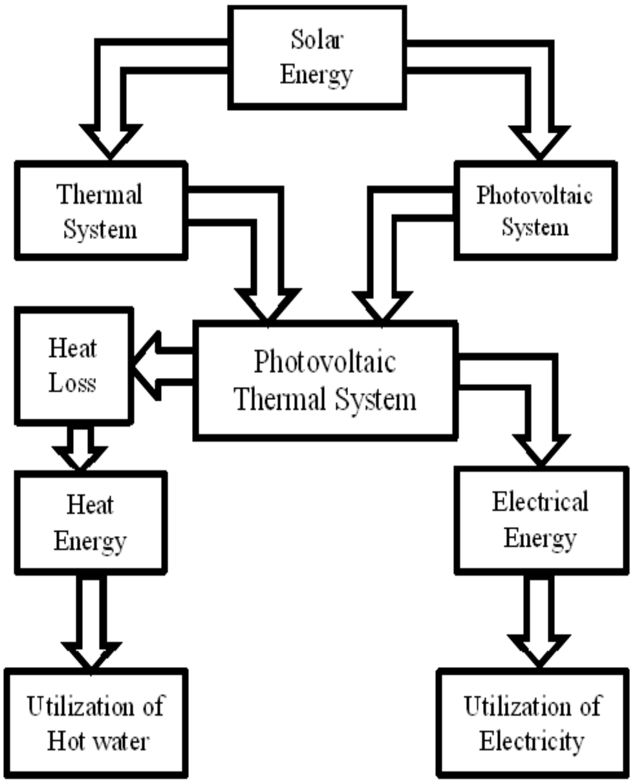
III. SOLAR PV/THERMAL HYBRID TECHNOLOGY

A PV–thermal (PVT) collector is a module in which the PV is not only producing electricity but also serves as a thermal absorber. In this way both heat and power are produced simultaneously. Since the demand for solar heat and solar electricity are often supplementary, it seems to be a logical idea to develop a device that can comply with both demands. Photovoltaic (PV) cells utilize a fraction of the incident solar radiation to produce electricity and the remainder is turned mainly into waste heat in the cells and substrate raising the temperature of PV as a result, the efficiency of the module decreased. The photovoltaic/thermal (PV/T) technology recovers part of this heat and uses it for practical applications. The simultaneous cooling of the PV module maintains electrical efficiency at satisfactory level and thus the PV/T collector offers a better way of utilizing solar energy with higher overall efficiency.

There are alternative approaches in PVT integration. Among many others, there can be selections among air, water or evaporative collectors, monocrystalline/polycrystalline /amorphous silicon(c-Si/pc-Si/a-Si) or thin-film solar cells, flat-plate or concentrator types, glazed or unglazed panels, natural or forced fluid flow, standalone or building-integrated features, etc. A major research and development work on the PVT technology has been conducted in the past few years with a gradual increase in the level of activities. The attractive features of the PV/T system are:

- It generates both electricity and heat simultaneously. The heat is utilized for water heating purpose.
- It is efficient and flexible: the combined efficiency is always higher than using two independent systems.
- Area required for PV/T system is less than the individual photovoltaic and thermal system. Because size of combined system is less, as we use one panel for solar photovoltaic and thermal system.
- This system is cost effective compared with individual systems. Reduced temperature increases the life of PV cell of the solar panel. [6]

IV. BLOCK DIAGRAM OF HYBRID PV/T SYSTEM



1. Solar Energy-

Solar energy is the electromagnetic energy that is released from the sun. The total of the solar energy arriving on earth is in significant compared to the enormous energy that is formed in the sun. The direct solar radiation can be transformed by the aid of various energy systems and devices into other beneficial energy forms, such as biochemical energy, thermal energy, and electrical energy.

2. Photovoltaic system-

The solar photovoltaic (PV) system are conversion in solar energy to electricity by using photovoltaic (PV) cells, also PV system or solar power system is a power system designed to supply usable solar power by means of photovoltaic. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling, and other electrical accessories to set up a working system.

3. Thermal system-

Thermal systems are conversion of solar energy into a water heating. A thermal water heating system have shown to offer savings of about 70–90% of total water heating costs and hence are one of the best candidates to greatly reduce house hold energy consumption. Solar water heating has become more sustainable, efficient, and economically feasible.

4. Photovoltaic Thermal system-

The both systems Photovoltaic and Thermal are independent and different. This both systems are including on panel says hybrid solar Photovoltaic Thermal system. In proposed model of PVT the functions of Photovoltaic Panels (PV) and thermal collectors can be integrated in a single device. In Photovoltaic-Thermal panel the sunlight is converted into electricity and heat simultaneously. Ultimately due to reduction in losses PV cell efficiency will be improved and with utilization of waste heat in solar cell we will get hot water.

5. Heat loss-

In all common types of solar cell efficiency is decreased with increase in temperature. This excessive temperature says heat loss. This heat loss is used to heating of water. The Reducing the solar cell temperature is one of the most effective way of increasing energy output and lifetime of the solar cell.

6. Heat energy and Utilization-

The heat energy is used to hot the water which is essential for both in industries and homes. It is required for taking baths, washing Clothes and Utensils, and other domestic purposes in both the urban and rural areas. Hot water is also required in large quantities in hotels, hospitals, hostels, and industries such as textile, paper, dairy, food processing, and edible oil.

7. Electrical energy and Utilization-

The major utilization of electrical energy is to generate output from electrical and electronics devices. Apart from it utilization of electric energy is in industry lighting, domestic utilization, in commercial usage, home appliances, in public service, etc.

V. CONCEPT OF THE PHOTOVOLTAIC /THERMAL COLLECTOR

The two main components of the PV/T unit are the PV module and the rest of the solar collector, which can be further divided into the glazing, the thermal absorber, the riser water tubes and the insulation layer. The backside/underside, and also side insulation layers reduce heat losses, while improving structural strength. The absorber–exchanger consists of a sheet-and-tube heat exchanger in which water flows in parallel pipes from the header inlet pipe to an outlet pipe on the upper side of the collector that collects the warm fluid. The transparent cover is a single glass sheet with a thickness thickness of 3.2 mm. (1) a PV-covered section that occupies a (variable) fraction P of the total collector area; and (2) an uncovered section that occupies the remainder of the area. This was done in order to study the effect of coverage of the unit with PV, by allowing a direct adjustment of the relative importance of the unit's electrical and thermal outputs electrical and thermal outputs.

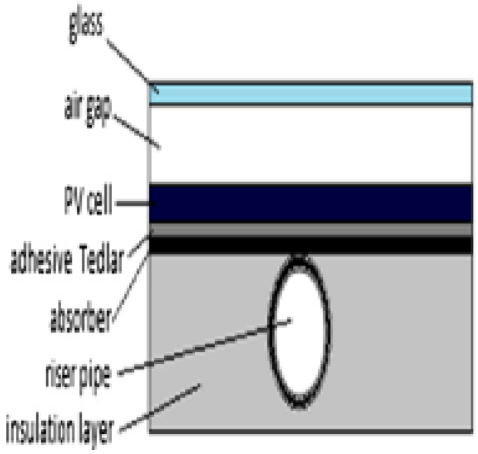


Fig 1 A PV-covered section that occupies a (variable) fraction P of the total collector area;

Furthermore, the absorber is completely isolated and cover with a full insulation protects the entire collector. For the modelling of the system (hybrid solar Collector PV/T) must take into account the method of fluid flow in the geometry of the absorber chosen, the type of PV cell used (PV module), the number of glass cover, the materials used for the back and side insulation. The quantity of solar energy received by the collector divided into three parts: an amount reflected, the Glass absorbs a portion, and the part transmitted to the plate of the absorber according to the construction of solar collector [8].

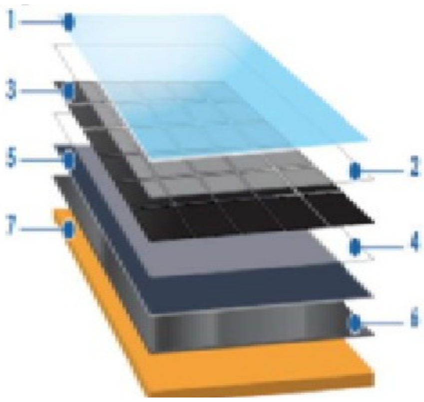


Fig 2 An uncovered section that occupies the remainder of the area.

VI. DIFFERENT TYPES OF COLLECTORS

A. Flat-plate PV/T collectors

The main concepts of flat-plate PV/T collectors were first introduced by Kern and Russell in 1978. Then, Hendrie presented a theoretical model for PV/T systems using conventional solar thermal collector techniques. Florschuetz extended the well-known Hottel–Whillier model developed for the thermal analysis of flat-plate collectors to the analysis of hybrid PV/T collectors. Flat-plate PV/T collectors can be categorized according to the type of working fluid used: water type, air type or combined (water/air) type flat-plate PV/T collectors. Air PV/T collectors are not efficient enough compared with the liquid ones. Although the manufacturing costs of air PV/T collectors are quite low, their applications are relatively few. Flat-plate PV/T collectors can be utilized as either grid connected or standalone systems.[9]

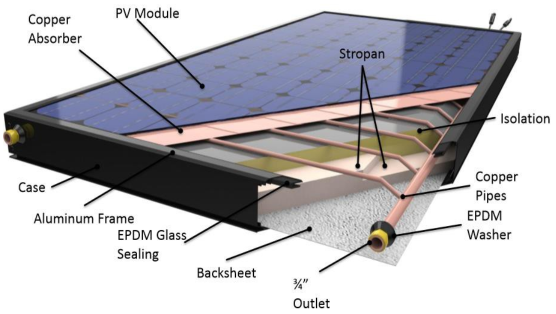


Fig 3. Cross Sectional View Of Flat Plate PV/T

B. Concentrating PV/T collectors

Concentrating PV and or PV/T systems can be classified with respect to the concentration ratio (CR). Winston proposed a new principle for collecting and concentrating solar energy. He underlined that concentrating systems with CR. 2.5 should use a system to track the sun, whereas for systems with CR, 2.5, stationary concentrating devices can be utilized. Sharan et al. carried out an analysis for the economic evaluation of concentrator-PV systems. Their results indicated that the cost of unit of energy produced by the concentrator PV systems decreases with increasing CR if both electrical and thermal outputs are collected for useful purposes. Al-Baali investigated the effects of illumination intensity and temperature on the performance characteristics of a solar panel. A reflecting mirror was utilized in order to concentrate sunlight on the panel surface and thus to enhance the current parameters. Garg etal presented a theoretical study to analyze the effects of plane reflectors on the performance of an air PV/T system. Performance of the system was determined for various combinations of reflectors. They recommend that the system cost can be reduced by replacing expensive PV cells with low-cost concentration devices. Garg and Adhikari investigated an air PV/T collector coupled with a compound parabolic concentrator (CPC). They observed that concentrating PV/T collectors provide higher efficiency compared with the systems without a CPC. Hatwaambo et al. analyzed the three reflector materials for fill factor improvements in a low–concentrating PV system: anodized aluminium, rolled aluminium foil and miro reflectors. The CPC element with a geometric CR of 3:6 was examined for different reflector materials. It was observed that the fill factors decreased from 0:72 for the reference module to 0:65 under concentration. The rolled aluminium reflector did not perform as expected in the fill factor enhancements. However, it is emphasized that the rolled aluminium reflector has a notable potential for use as the PV-CPC reflector for cost reduction. The cost of rolled aluminium is two or three times less than that of anodized aluminium and six times less than that of the miro reflector per square-meter. Solanki et al. developed a Vtrough PV module for better concentration and heat dissipation as shown in Figure 3 .The V-trough channels were constructed using a thin single Al metal sheet. Six PV module strips each containing a single row of six mono crystalline silicon (c-Si) cells were fabricated and mounted in six V-trough channels to achieve concentration. Experimental results indicated that the cell temperature in the V-trough module remains nearly same as that in a flat-plate PV module, despite light concentration. Conversion efficiency of the V-trough PV module is 17:1% which is 62% higher than the flat-plate PV module. Researchers attempted to enhance the hybrid water PV/T collectors.[9]

VII. MATHEMATICAL MODEL

In the literature there are many theoretical and experimental works on PV-T collectors to evaluate the energy yield of systems with various configurations. Numerical/mathematical models, with variable levels of complexity, are analysed. Other studies regarding numerical models that can represent the behaviour of the PV-T panel are available in the literature.

In this paper, the mathematical model for the PV-T was developed. The model has been implemented in the Matlab/Simulink software environment and validated evaluating the PV-T performance of a panel. Literature values were taken as starting values for the model parameters and then fine-tuned in order to perform an accurate calibrate of the model for the PV/T.

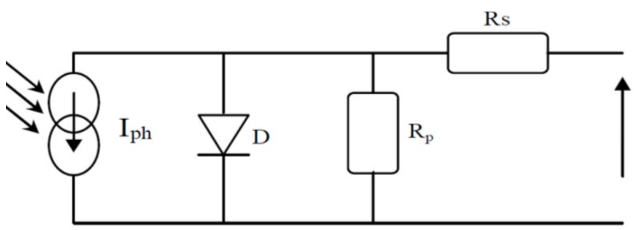


Fig. 4. Equivalent circuit for PV cell

The performance of electrical system will be determined using procedure to that of single system analysis. As a mean to explain formula used to calculate electrical performance consider a common mathematical model.

A simplest equivalent circuit of a solar cell is a current source in parallel with a diode. The output of the current source is directly proportional to the solar energy (photons) that hits on the solar cell (photocurrent Iph). During darkness, the solar cell is not an active device; it works as a diode, i.e. a p-n junction. It produces neither a current nor a voltage. However, if it is allowed to connect to an external source (large voltage) it generates a current Id, called diode (D) current or dark current. The diode determines the VI characteristics of the cell [10].

$$Voc = 0.625 * Ns \qquad (1)$$

Where,
Voc is represented as Open circuit voltage
Ns is No of cells in panel.

$$Vt = (K * Tc)/q \qquad (2)$$

Where,
Vt is terminal voltage
K is Boltzmans constant
Tc is Cell temperature
q is Electron charge

$$a = Ns * A * Vt \qquad (3)$$

Where,
Ns is No. of cells in panel
A is Ideality factor

$$Ioref = Isc * exp(-Voc/a) \qquad (4)$$

Where,
Isc is short circuit current

$$Io = Ioref * \left(\frac{Tc}{Tref}\right)^3 * \exp * \left(\frac{q*1.1}{A*K}\right) * \left(\left(\frac{1}{Tref}\right) - \left(\frac{1}{Tc}\right)\right) \qquad (5)$$

Where,
Tref is Standard reference temperature

$$Iph = \left(Isc + Ki * \left(\frac{Tc}{Tref}\right)\right) * \left(\frac{G}{Gref}\right) \qquad (6)$$

Where,
Ki is Temperature coefficient of cells short Output voltage
Gref is solar irradiance standard value
G is solar irradiance
Iph is phase current

$$Id = \text{Io}\left(exp\left(\frac{Vd}{a}\right) - 1\right) \qquad (7)$$

Where,
Vd Cell voltage

$$V = Vd - (I * Rs) \qquad (8)$$

$$P = V * I \qquad (9)$$

Where,
V is Output voltage
I is Output current

$$\eta = \frac{V * I * FF}{G} \qquad (10)$$

Where,
η is efficiency
FF is Fill Factor

- *Solar Photovoltaic Thermal Part*

The overall electrical efficiency of system can be calculated as

$$\eta ele = \eta(1 - 0.04(Tpm - NOCT)) \qquad (11)$$

Where,
ηele is Electrical efficiency of hybrid PV/T
NOCT is Normal operating cell temperature
Tpm is Mean temperature

An expression for thermal efficiency of a system can be obtained as

$$\eta th = FR(s * \tau apv) + (1 - (s * \tau at)) - FR * Uloss\left(\frac{Ti - Ta}{G}\right) \qquad (12)$$

Where,

ηth is Thermal efficiency of hybrid PV/T
(τα)t is Thermal transmittance/absorber
(τα)pv is PV transmittance/absorber
S is Packing factor

$$Tpm = Ti + \frac{\left(\frac{Q}{Ac}\right)}{FR * Uloss}(1 - FR) \quad (13)$$

Where,

FR is Heat removal efficiency factor
Ul is Collector heat loss coefficient
Ti is Inlet temperature
Ta is Ambient temperature

$$Q = Ac * FR[(\tau\alpha)pv * G - Uloss(Ti - Ta)] \quad (14)$$

Where,

Q is collector heat gain
Ac is collector area
G is solar irradiance

VI. SIMULATION PERFORMANCE

A MATLAB/SIMULINK model which is shown in fig .The dependence of thermal efficiency on the ratio of temperature difference between the collector inlet and ambient (Ti-Ta) relative to the global solar radiation incident on the collector surface (G) is carried out at various parameters.

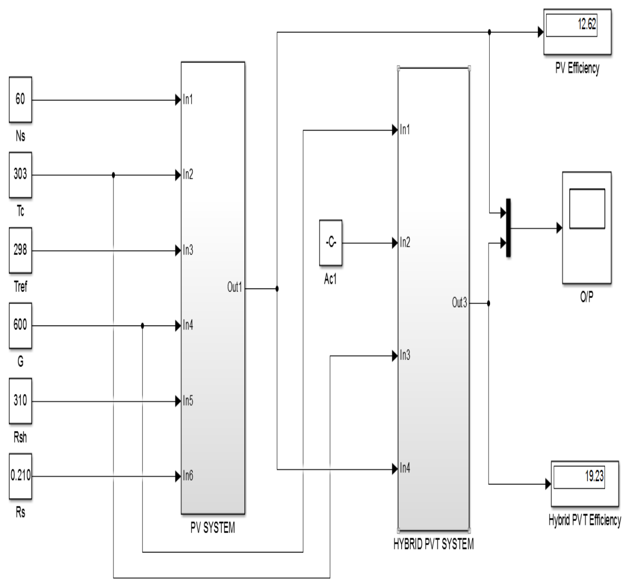


Fig.5. PV/T collector diagram using MATLAB/SIMULINK

VII. OUTPUT RESULT

The output results of PV system are shown in fig.6. In this system the efficiency are increases at particular temperature and above that temperature the efficiency was decreases.

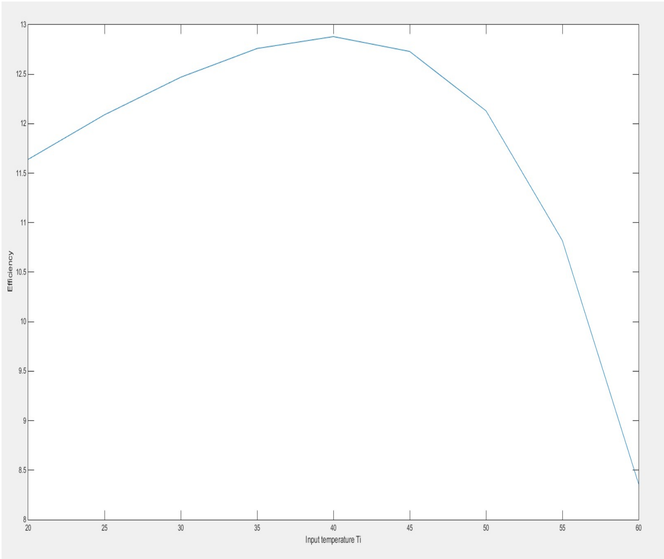


Fig 6 Efficiency Vs Input temperature of PV system

The fig.7 shows that the result of hybrid PVT system. From this system we getting increased efficiency of PV system.

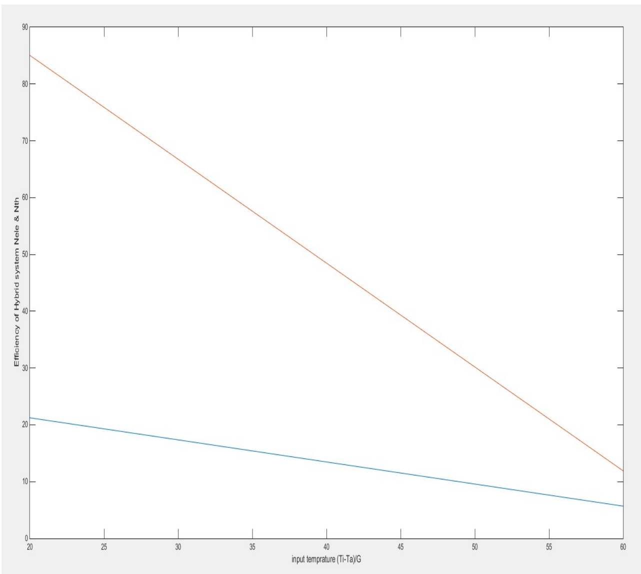


Fig 7 Efficiency Vs Input temperature

The obtained results are shown in below graph. The efficiency of individual PV panel is 13% and that of combined photovoltaic thermal system is 21% which is increased in this system.

VIII. COMPARISON OF INDIVIDUAL PV AND THERMAL SYSTEM WITH HYBRID PVT

Parameter	PV and Thermal	Hybrid PVT
Area of panel	Area of panel is more because two individual panels are required	Area of panel is less because Only one panel required
Size of system	Overall size of system is more than hybrid PVT system	Overall size of system is less than PV and Thermal system
Losses	Heat losses are more	Heat losses are reduced in this system
Efficiency	Efficiency of individual PV system is less	Hybrid PVT system are more efficiency
Cost	Cost is higher as compare to hybrid PVT system	Cost is less as compare to individual PV and Thermal system
Life	Life of photovoltaic cell is less	Life of photovoltaic cell is more

From this comparison we conclude that Hybrid PVT system is more efficient and reliable than individual PV and Thermal system.

CONCLUSION

Efficiency of photovoltaic system is depends on the temperature of system. When temperature increases about normal operating range then efficiency of PV system decreases. Thus the hybrid solar PV/T system is the system used to improve the efficiency of panel. From this system we can obtain electricity as well as hot water due to circulation of water at rear side of panel. Also hybrid solar PV/T system is cost effective, requires less space compared to independent photovoltaic and thermal systems.

In this system the photovoltaic panel temperature is significantly reduced by 10-15% due to flow of water through the collectors at the rear side of PV panel. This kind of systems is suitable for residential, industrial, also in hospitals where requirement of both electricity and hot water.

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