Heliostat Based Solar Park: Heating and Generation Combined

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***Abstract*— A heliostat (from Helios, the Greek word for sun, and stat, as in stationary) is a device that includes a mirror, usually a plane mirror, which turns so as to keep reflecting sunlight toward a predetermined target (solar panel), compensating for the sun's apparent motions in the sky. Nowadays, most heliostats are used for day lighting or for the production of concentrated solar power, usually to generate electricity. They are also sometimes used in solar cooking. The proposed system would be used to generate the electric power from sunlight and provide thermal energy by heating water for industrial processes like processing food. Its speciality lies in the structural frame consisting of PV cells and water tubes.**

Keywords—Solar, Helistat, Park

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I. INTRODUCTION

Renewable energy is defined as energy that comes from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy has the potential in replacing the conventional fuels in four areas namely electricity generation, air and water heating/cooling, motor fuels, and rural (off-grid) energy services. The Sun is the source of energy on Earth, its because of sun that there is change in weather and climate. Efficient and economic harnessing of solar power may be very significant for taking care of today’s ever-growing energy needs.

Solar energy can be harnessed by either converting solar energy to thermal energy or by converting solar energy to electricity. Converting solar energy to thermal energy can be for heating purposes or for electricity generation purposes. There has been a new addition which is Photovoltaic/Hybrid technology. Here combination of the two technologies by offering thermal energy and electricity simultaneously from a single solar collector is done.

Solar thermal systems (heating purposes) are usually small scale systems that which meet the heating demands of a facility. Here a fluid, which can be water/water-mixture or air, is circulated through an absorber. The outlet temperature of the fluid is higher than its inlet temperature. Solar systems (generate electricity) are large scale systems involving parabolic trough collectors, Fresnel mirrors or concentrating solar towers to generate heat and then this heat is used to increase the temperature of the running fluid in-turn the heat inside the fluid is converted to electricity using a steam turbine and generator. Other way can be use of photovoltaic modules. An emerging technology, combining the two ways of harnessing solar power is Photovoltaic or Thermal hybrid collectors. This paper investigates the performance of Photovoltaic/Thermal hybrid collectors. Photovoltaic/Thermal hybrid collector consists of a PV layer at the top and an absorber layer beneath it which absorbs heat from the PV layer. For fluid circulation the absorber layer has an inlet and outlet ports. Water or water-ethylene-glycol mixture or air is circulated through the absorber material to extract heat from it.

II. REVIEW

Photovoltaic (PV) module efficiency conversion [1] is affected by environmental changes, particularly by variations in temperature and radiation. There are several devices and techniques that allow a minimization of those effects and changes, by keeping the efficiency conversion at its highest level. Maximum Power Point Tracking (MPPT) and PV cooling systems can provide this efficiency improvement. In this paper it is proposed an association and combination of those systems, with the intent of achieving an even greater efficiency conversion level and also as a suggestion for future works in this area. In [1], a generic model of such system was presented. An exergy analysis was performed [2] to compare a conventional

(1) two panel photovoltaic solar thermal hybrid (PVT x2) system,

(2) side by side photovoltaic and thermal (PV + T) system,

(3) two module photovoltaic (PV) system and

(4) a two panel solar thermal (T x2) system with identical absorber areas to determine the superior technical solar energy systems for applications with a limited roof area. Three locations, Detroit, Denver and Phoenix, were simulated due to their differences in average monthly temperature and solar flux. The exergy analysis results show that PVT systems outperform the PV + T systems by 69% for all the locations, produce between 6.5% and 8.4% more exergy when matched

against the purely PV systems and created 4 times as much exergy as the pure solar thermal system. The results clearly show that PVT systems, which are able to utilize all of the thermal and electrical energy generated, are superior in exergy performance to either PV + T or PV only systems. These results are discussed and future work is outlined to further geographically optimize PVT systems

Concluding their study, they authors found that for solar energy collecting systems with identical absorber areas, PVT hybrid systems surpassed the exergy efficiency of both PV + T (side by side) and purely PV systems in three representative regions in the U.S. The PVT system outperformed the PV + T system by 69% and the Tx2 system by almost 400% in all the locations. Similarly, the PVT system performed 6.5%, 7.2% and 8.4% better than the PV only system for the Detroit, Denver and Phoenix locations respectively. It is clear that for applications with limited roof area PVT systems are superior choices. This research also suggests that greater optimization is required for PVT systems. To further improve the exergy performance of PVT systems, geographical optimization should be further investigated with potential improvements found in the PV material, flow rate and improved thermal loss reductions.

Previous work has shown that high-temperature short-term spike thermal annealing of hydrogenated amorphous silicon (a-Si:H) photovoltaic thermal (PVT) systems results in higher electrical energy output [3]. The relationship between temperature and performance of a-Si:H PVT is not simple as high temperatures during thermal annealing improves the immediate electrical performance following an anneal, but during the anneal it creates a marked drop in electrical performance. In addition, the power generation of a-Si:H PVT depends on both the environmental conditions and the StaeblereWronski Effect kinetics. In order to improve the performance of a-Si:H PVT systems further, this paper reports on the effect of various dispatch strategies on system electrical performance. Utilizing experimental results from thermal annealing, an annealing model simulation for a-Si:H-based PVT was developed and applied to different cities in the U.S. to investigate potential geographic effects on the dispatch optimization of the overall electrical PVT systems performance and annual electrical yield. The results showed that spike thermal annealing once per day maximized the improved electrical energy generation

The electrical and thermal performance of a typical single pass hybrid photovoltaic/thermal (PV/T) air collector was modeled by [4]. They also simulated and analyzed two selected case studies in Iraq. An improved mathematical thermo-electrical model was derived in terms of design, operating and climatic parameters of the hybrid solar collector to evaluate its important characteristics: collector flow and heat removal factors, PV maximum power point and its temperature coefficient, and overall power and efficiency. Unlike previous PV/T thermal models, the present model is obtained with some additions and corrections in radiation and convection heat coefficients for the top loss and for the air duct with more applicable sky temperature correlation. The well-known 5-parameter electrical model of PV module was solved using improved boundary conditions and translation equations for better convergence and accuracy. The voltage temperature coefficient of the PV module was included in the boundary conditions for convergence stability. The module parameters were taken to be dependent on solar radiation and PV cell temperature for improved accuracy. A Matlab computer simulation program is developed to solve the thermo-electrical model. The developed model is verified with previously published experimental results and theoretical simulations; it is proved to be most accurate in respect to percentage errors and correlation coefficients. Different parameters of the PV/T collector such as cell and air temperatures, thermal gain, PV current and voltage, and fill factor have been investigated. The results identified the effects of most important operating conditions such as sky, inlet and cell temperatures, air flow rate and incident solar radiation on the performance of the hybrid collector. The approved model was applied for a winter day (22 January 2011) in Baghdad city and for a summer day (20 May 2011) in Fallujah city. It was found that the electrical, thermal and overall collector efficiencies for the two case studies were 12.3%, 19.4% and 53.6% respectively for the winter day, while that for the summer day were 9%, 22.8% and 47.8%

In its conclusion it was seen that an improved thermo-electrical model was developed for a typical PV/T air based solar collector. The model was verified with previously published results and then applied to two selected cases, winter and summer, in Iraq. No previous study has been found for hybrid PV/T solar collector under Iraq climate. Following are few observations concluded form the study

1.1. *Thermal characteristics*

1. The gain, efficiency, and collector efficiency and heat removal factors were found to be better in the summer than that in the winter due to lower heat loss coefficient. The thermal gain is considerably higher (2.7 times at mid-day) due to very high solar radiation at the summer of Fallujah city. However, the other characteristics are not much improved due to the relatively high heat loss arise from the dry climate of Fallujah.
2. The variation of thermal efficiency during the day in the winter was larger than that in the summer. This was due to smaller thermal energy is available at low solar radiation (as in the morning and afternoon of winter day) as compared to the electrical energy absorbed and heat loss.
3. The collector flow factor is relatively high for both cases. This indicates that the air flow in the duct is adequate, i.e. the average air temperature is near to the inlet temperature. However, due to high heat loss, the collector efficiency factor was low and consequently the heat removal factor was also low. This indicates that the collector operates, in the winter and the summer, at high cell temperature relative to the inlet temperature. In fact, the heat removal factor can be improved by further increase of duct air velocity; however, this requires higher power air fans.
4. The radiation heat coefficient in the air duct was found to be comparable to the convective heat

coefficient of the fluid (air). This contributes in reducing the collector efficiency factor.

5. It was found that the heat loss is mainly due to top losses from the collector; 70% of these losses are due to the radiation heat transfer from glass to ambient because of low wind speed. The sky temperature affects considerably the radiation losses. The latter are much reduced when sky temperature is closer to the ambient temperature. This condition was applied for the hot moist climate which is not applicable to Iraq climate. This justifies the use of more applicable correlation for sky temperature. In fact, the top losses are very much reduced using a glass cover at appropriate spacing from the PV module.

1.2 Electrical characteristics

1. While the output power in the summer is higher than that in the winter (1.7 times at solar noon); the opposite is true for the efficiency. This is due to the negative temperature coefficient of efficiency. In addition, there is a little variation in the efficiency during the day in the winter and summer due to the relatively small value of its temperature coefficient.
2. To maintain the operation of the PV module at the maximum power point, the electrical load needs to be decreased when the climate changes from winter to summer. This can be achieved using maximum power point tracker.
3. The fill factor is higher in the winter than that in the summer. It is found that the fill factor gives a measure of the maximum electrical efficiency.

1.3 Overall characteristics 1. During the effective hours of the day, the thermal gain and its efficiency are found to be higher than the electrical output power and its efficiency respectively in the winter and summer. However, considering the thermal power conversion factor, the opposite is true. This is due to the high heat loss in the collector. The relative electrical-to-thermal equivalent power and efficiency are higher in the winter than that in the summer. Thus, the overall equivalent efficiency in the winter is higher than that in the summer.

In his paper [5], thermal and electrical performance of PV/T collectors have been analysed and presented for the climate of RAK, UAE. Thermal performance evaluation has been done following the collector output model presented in European standard and electrical performance evaluation is done by analyzing the effect of water circulation on the performance of PV/T collectors. Additionally, a PV/T system has been designed for residential use in UAE and simulated using simulation software Polysun. Power output and requirements of the system along with its financial analysis was also presented. Alternative solar energy systems to PV/T system have been analyzed in terms of power output, specific requirements and financial analyses. Finally, a study is made to reveal the impact of incentives towards sustainable energy systems on the economic feasibility of PV/T systems for residential use in UAE.

In its conclusion, author has observed that by combining thermal and electrical aspects of solar panels, an increase in electrical output is experienced due to the reason that the water circulation through the collector decreases the overall temperature of solar cells, which lead to a performance increase in terms of electricity production. This effect is experienced in the experiments that are conducted on the PV/T module, an increase in electrical output is recorded when there is a flow through the collector in comparison to the case where there is no flow through.

The benefits of PV/T systems are reaped most when there is a demand for both electricity and heat. It is observed that the electricity output of a PV/T collector is already greater than a similar sized PV collector. Adding the thermal output to that, having a PV/T system is most advantageous there is a demand for heat as well besides the increased electricity output. If there is a demand for heat only, having a solar thermal system would be more appropriate due to greater thermal performance and better economic feasibility of solar thermal systems. In case of electricity demand only, designing a PV system would be more suitable due to lower costs although PV/T systems offer better performance in electricity production.

[6]illustrated that , Integrating renewable energy (RE) systems into the built environment and using available rooftop space for solar energy installations provide a number of financial and societal benefits.These benefits include cost savings, increased energy cost security, and reduction of greenhouse gas emissions. Utilization of available rooftop area also provides an opportunity to implement solar energy technologies such as photovoltaic (PV) and solar hot water (SHW) systems to generate electricity and hot water for those buildings. The Project findings are that because of complications in system design and conflicts in installation and commissioning, the process did not deliver results that would be representative of future installations. TRNSYS was used to model the solar thermal system and SolOpt software was used to model the impacts of panel cooling on PV production. The basic system characteristics of the ideal system are outlined below:

- 48 solar thermal collectors installed on the back of typical crystalline silicon PV panels
- 1800 liters of storage
- Typical Office building draw profile (5000 liters/day on weekdays and 0 liter /day on weekend)
- 150-Watt circulation pump
- Standalone boiler provides supplementary heating (electric boiler)
- Tank temperature set point 125 °F
- Mixing valve set point temperature 120 °F

The primary disadvantage of the technology is the lower thermal efficiency, which requires greater surface area to provide an equivalent amount of solar thermal energy. Ultimately, the total system cost must be 30% to 50% lower than the cost of traditional solar thermal systems to be cost competitive. In the future, the technology should be evaluated against a standard solar thermal and separate PV system by an independent energy analyst using an hourly analysis tool. Installations should focus on hotter climates with good local solar incentives, facilities with electric hot water heaters, and high electric rates that can fully capture the benefits of panel cooling and apply the best practices as listed above.

[7] in their paper said that ,Hybrid photovoltaic thermal (PVT) systems consist of PV modules and heat extraction units mounted together. They convert the absorbed solar radiation into electricity and circulating water or air which are heated by cooling the PV modules. The PVT systems using water (PVT/WATER) for heat extraction are more expensive than air type PVT systems and can be used all seasons, mainly in low latitude applications, as water from mains is usually under 20ºC. In this paper they presented the design aspects for the hybrid PVT/WATER systems that can be applied in residential buildings, hotels, etc, aiming to provide electricity and hot water. They suggested the systems are analyzed regarding the design concepts and the electrical and thermal conversion effect for different PV module configurations. Their study was focused to small size PVT/WATER systems that can be applied to one family houses, multiflat residential buildings, small hotels, etc and can be used alternatively to the widespread thermosiphonic solar systems, in stand-alone and mini-grid application of photovoltaics. Additionally, in their study the application of a booster diffuse reflector, which increases the solar radiation on PVT panel aperture surface and overcomes in a way the reduction of the electrical output due to the optical losses from the additional glazing.

Further they concluded that the application of PVT/WATER systems is effective in electrical output, reducing cost pay back time (by 2.5 and 4.5 times regarding that of the typical pc-Si and a-Si PV modules. The addition of the thermal unit for the water heating contributes to a satisfactory total energy output, which is more effective for the pc-Si PVT than for a-Si PVT type systems. The cost pay-back time (of all considered hybrid systems is considered encouraging as they are less than 8 years, with better results for the a-Si type systems (about 5 years).The diffuse reflector increases the electrical and thermal output, but without significant improvement of cost pay-back time. These results show that PVT/WATER systems are of interest for application and wider use of photovoltaics

[8] concluded that Photovoltaic thermal system is better than unique PV module system because the energy can be recycled and the PV module can be cooled to increase the electrical efficiency. In their study, the prostulated that PV/T system that can be installed be PV/T module, storage tank, pump and controller. In the normal distribution of daily solar radiation condition, Water temperature in the storage tank can be heated up to 40 degrees. The PV/T system was found with high thermal efficiency about 35.33 to 47.21% and the electrical efficiency of 12.77 to 14.46%. The results obtained practically indicated that the system thermal efficiency reached 35.33% and photovoltaic conversion efficiency can reach 12.77% during the testing period. The water tank temperature can be risen from 26.2 degree to 40.02 degree.

[9] states that PV modules generate electricity, but the electrical output is only one component of the total energy produced by a photovoltaic array. A typical photovoltaic (PV) module has an ideal conversion efficiency in the range of 15%. The remaining energy produced is heat, which is neither captured nor utilized. This heat increases the operating temperature of the PV modules, which actually decreases their overall performance. Recent scientific testing done in conjunction with the International Energy Agency Task 35 Project at Canada’s National Solar Test Facility has shown that it is possible to capture almost two to three times more thermal energy than electricity from a PV array. Panels from various manufacturers were tested under conditions, and the results showed that when PV modules were mounted on top of SolarWall transpired collector panels, the total solar efficiency increased to over 50%, compared to the typical 10 to 15% for PV modules alone. By removing the excess heat generated by the PV modules, the electrical output is increased. Modules can commonly operate at temperatures over 50 degrees C above ambient temperature, resulting in a performance reduction of more than 25%. By dissipating the heat from the module and lowering the operating temperature, significant gains can be made in system performance and the heat can be utilized for practical heating purposes. As a result of these effects, the testing showed that the payback on a PV system that incorporates a thermal component could be reduced by between one third and one half.

Concluding his research, [9] states that test results from the National Solar Test Facility indicate that mounting the PV panels above SolarWall thermal panels will lower the PV panel temperature to an acceptable level. Lowering the cell temperature also increases the power output. The power output for the panels from BP and Evergreen increased at a rate of between 0.4% to 0.5%/ per degree C of lower module temperature. The tests confirmed that the thermal energy was much larger than the electrical energy, between 150% to 400% higher for the crystalline PV panels and as much as 800% higher for the amorphous panels. For example, a 160 Watt PV panel actually produced over 700 Watts of total energy with 540 Watts of thermal energy making up the difference. The solar heat is normally used during the heating season whereas the electrical output is useable over twelve months. Heating air with the transpired collector is cost effective with only 5 - 9 months of utilization and should also be cost effective with PV/T. When space heating is not required, the solar thermal energy can be easily vented. If however, the summer solar heat can also be used for clothes drying, water heating, pool heating or process heating, then the economics improve even more. The tests showed a temperature rise of 6 to 20°C above ambient. If a higher temperature is desired, a two stage solar heating system can be designed with the first stage as PV/T panel system and the second stage a glazed solar panel to receive solar preheated air from the first stage. It is desirable, however, to develop other uses for the heat in the summer months to make a PV thermal system even more cost effective, such as a desiccant cooling system. Utilizing the summer heat will improve the economics of a project and at the same time, recover heat that would otherwise be rejected to the atmosphere. These test results warrant investigating the application of PV/T systems in various geographical areas and climate zones, with and without the various incentives for PV installations. [9] further concluded that all building integrated PV installations should evaluate the benefits of utilizing the rejected heat.

[10] states that a significant amount of research and development work on the photovoltaic/thermal (PVT) technology has been done since the 1970s. Many innovative systems and products have been put forward and their quality evaluated by academics and professionals. A range of theoretical models has been introduced and their appropriateness validated by experimental data. Important design parameters has been identified. Collaborations have been underway amongst institutions or countries, helping to sort out the suitable products and systems with the best marketing potential. This article gives a review of the trend of development of the technology, in particular the advancements in recent years and the future work required. In the summary of this paper they stated that , the performance of various PVT collector types had been studied theoretically, numerically and experimentally for more than three decades. A range of PVT systems and products has been put forward and evaluated by researchers and professionals on various occasions. Their endeavour has been reviewed in this article. Generally speaking, in the early work, the research efforts were on the fundamental theories, the consolidation of the conceptual ideas and the feasibility study on basic PVT collector design configurations. In the 1990s, the PVT studies were more related to the collector design improvement and cost-performance evaluation. There were more rigorous analyses of the energy and mass transfer phenomena on conventional collectors with experimental validation. The ideas of building-integrated design began to emerge and the demonstration projects made available for documentation. In the last decade however, the focus has been generally shifting towards the development of complimentary products, innovative systems, testing procedures, and design optimization.

It was concluded in this paper [11] that the application of PV/T systems is effective in electrical output for lower PV module operating temperature, which corresponds to high thermal energy output, but to lower fluid temperature rise. The results determine the limits of the practical use of PV/T systems and regarding the use of a-Si or pc-Si PV modules, the higher electrical efficiency of pc-Si PV modules make them more effective considering the available area for their installation. The payback time under 10 years for PV/T hybrid systems is an opportunity for a large potential market for the PV industry, as the industry environment needs products that can be marketed without or with lower subsidy support

Solar energy can be converted directly into electric and thermal energy through photovoltaic cells and thermal collectors, respectively [12]. However this conversion, in particular the photovoltaic, has a reduced efficiency. A solution proposed to increase this efficiency is with the hybrid solar structure, which consists in the junction of the photovoltaic panel and the thermal collector in a single module. The paper presents a review of the research in this area, presenting the definitions of the related collectors and results of their characteristics, as well as some ideas for future studies. In their concluding remarks [12] said that the work has presented a review of the available literature on PV/T collectors, mainly of flat plate type. The results show that the PV/T efficiency is sensitive to many variables and a more detailed study seems to be necessary in order to obtain an optimal PV/T collector with improved efficiency and reduced costs, in order to be economically competitive.

The utilization of solar energy can be made by photovoltaic (PV) cells to generate electric power directly and solar thermal (T) panels can be applied to generate heat power. When the utilization of the solar energy is necessary to generate electric power, the option of using T panels [13] in combination with some heat / electric power conversion technology can be a viable solution. The power generated by utilizing the solar energy absorbed by a given area of solar panel can be increased if the two technologies, PV and T cells, are combined in such a way that the resulting unit will be capable of co-generation of heat and electric power. In their paper, combined Photovoltaic / Thermal panels were suggested to generate heat power to produce hot water, while the photovoltaic part is used to obtain electric power mainly for covering the electric power consumption of the system, to supply the electronic control units and to operate pump drives etc. AC and DC supplies are provided by converters for covering self consumption and possibly the need of some household appliances. The development and design of the system was made by extensive use of modelling and simulation techniques. In their paper as part of the simulation studies, they carried out tests to determine the energy balance in the electric energy conversion section of the system and the control structure, assuming stand-alone(SA) operation. In the concluding remarks , [13] conclude that a system suggested for utilizing solar energy for the production of heat and electric energy, based on the application of combined photovoltaic / solar thermal panels, can be operated in parallel or SA mode, but there only SA mode has been studied. The analysis of the complex system requires extensive use of simulation techniques and Matlab / Simulink as well as PSIM models have been described that can be used to study the energy balance of the section connected with the PV part of the combined panels and the operation of the MPPT controller. System have been built and tested by [13[, computer simulation and test results confirm expectations. It can be concluded that the system suggested hereby is technically feasible, however, they concluded that the economy of the solution needs further investigations

The Combined Heat and Power Solar System, or CHAPS system being developed at the Australian National University, has been described as a concentrating parabolic trough system that combines photovoltaic (PV) cells to produce electricity with thermal energy absorption to produce hot water. The first CHAPS prototype is a 25x concentration domestic style system, suitable for hot water and electricity generation for a home. [14] Recently a second CHAPS system prototype has been developed, a 35x concentration single-axis tracking system, designed for installation on the roofs of commercial and light industrial buildings, to contribute to building heating, cooling and power requirements. The development of the CHAPS systems was preceded by PV trough technology development at the ANU since the mid-1990s, culminating in the commissioning of a 20kW PV trough array at Rockingham, Western Australia, in 2000.It has been concluded by [14] that results from the first CHAPS collector indicate thermal efficiencies around 50% and electrical efficiencies upward of 10% are achievable throughout the sunlight hours of the day. It is expected that recent developments in the design of the receivers and mirrors since the first prototype will further improve both thermal and electrical efficiency.

[15] compared the performance of an integrated photovoltaic and thermal solar system (IPVTS) to a conventional solar water heater and demonstrated the idea of an IPVTS design. A commercial polycrystalline PV module was used for making a PV/T collector. The PV/T collector was used to build an IPVTS. The test results show that the solar PV/T collector made from a corrugated polycarbonate panel can obtain a good thermal efficiency. Their study introduces the concept of primary-energy saving efficiency for the evaluation of a PV/T system. The primary-energy saving efficiency of the present IPVTS exceeds 0.60. This is higher than for a pure solar hot water heater or a pure PV system. The characteristic daily efficiency reaches 0.38 which is about 76% of s the value for a conventional solar hot water heater using glazed collectors. The performance of a sPV/T collector can be improved if the heat-collecting plate, the PV cells and the glass cover are directly packed together to form a glazed collector. The manufacturing cost of the PV/T collector and the system cost of the IPVTS can also be reduced. The present study shows that the idea of IPVTS is economically feasible too.

In their paper [16] , made an attempt to evaluate and compare the energy matrices of a hybrid photovoltaic thermal (HPVT) water collector under constant collection temperature mode with five different types of PV modules namely c-Si, p-Si, a-Si (thin film), CdTe and CIGS. The analysis is based on overall thermal energy and energy outputs from HPVT water collector. The temperature dependent electrical efficiency has also been calculated under composite climate of New Delhi, India. It is observed that c-Si PV module is best alternative for production of electrical power. Maximum annual overall thermal energy and exergy is obtained for c-Si PV module. The maximum and minimum EPBT of 1.01 and 0.66 years on energy basis is obtained for c-Si and CIGS respectively, whereas on exergy basis maximum EPBT of 5.72 years is obtained for a-Si and minimum of 3.44 in obtained for CIGS PV module. EPF and LCCE increase with increasing the life time of the system.

Solar photovoltaic/thermal (PV/T) water collector system was designed and developed at MANIT Bhopal to test its performance by [17]. Solar photovoltaic/thermal (PV/T) system consisted of PV modules coupled with heat extracting media such as water or air. Solar photovoltaic/thermal (PV/T) collector produced both thermal energy and electricity simultaneously. [17] concluded that the electrical efficiency of a PV system drops as its operating temperature rises. Design of solar PV/T system was aimed to reduce the operating temperature of PV modules and to keep the electrical efficiency at sufficient level. This paper presented a performance evaluation of flat plate solar PV/T collector and comparing its performance with the solar PV system. Experiments were conducted with fixed water flow rate of 0.002 kg/sec and different initial water temperature in the outdoor environment. With the proposed design and operating condition the daily electrical efficiency was about 7.57%, the daily thermal efficiency was about 50.1%, and the total efficiency of the system exceeded 73%. The energy saving efficiency of the PV/T system exceeded 68%.The results show that the electrical and thermal performance of the combined PV/T system is much more than that of employing the PV alone. PV/T application can offer sustainable solution for maximizing the solar energy output from building integrated photovoltaic system. This kind of PV/T system is especially suitable for low temperature applications like pre-heating of domestic water.

III. OBJECTIVES OF THE CURRENT RESEARCH

A lot many application are needed to be studied from where the energy can be regenerated, many of such techniques are still unutilized; this is the motivation for envisaging the project. The main objective of the propose project work are:

- Developments of hybrid PVT so that the dual mode of energy can be processed where in water heating along-with electricity can be generated
- Integration of photovoltaic and water heating structure
- Analysis of maximum heat production and electricity generation
- Monitoring of the real time data.

This project will enhance and will provide facilitation for energy harvesting deployment in different scenarios. This project utilizes the direct sunlight as well as diffused sunlight which is being utilized using the heliostat. A 1100 liter tank along with 4 solar panels of 250 W each will be used in this project. A power conditioning unit will be used to monitor and control the flow of power. Sunlight will be directed towards the mirrors and concentrated power will be reflected to the PV cell array structure. The design will be indigenous and have layered structure where first heating will be done and then electricity will be generated via diffused light.

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