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A STUDY OF THE ECONOMICS AND USES OF PHOTOVOLTAIC THERMAL HYBRID SOLAR TECHNOLOGY

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ABSTRACT

Photovoltaic technology has advanced rapidly in recent years; with studies showing that only around 20% of solar energy is turned into electricity, while more than 50% of incoming solar radiation is converted into heat. By eliminating the surplus heat, the electrical efficiency and operating temperature of PV modules may be increased. As a result, the PVT collector, a hybrid collector, was born. PV cell cooling has become an essential research topic in order to enhance PV panel efficiency, power output, and performance characteristics. For several hybrid PVT solar collector designs, many theoretical, experimental, and economic investigations have been conducted. In various applications, other alternative concepts may be better. This article examines the historical and current trends in PVT technology development, focusing on the performance and economic feasibility of PVT systems in various application areas. Future suggestions and critical evaluations will be made in order to overcome the obstacles and difficulties that are preventing the advancement of PVT technology.

KEYWORDS: *Efficiency, Photovoltaic, Photovoltaic Thermal (PVT), Solar Energy, Thermal.*

1. INTRODUCTION

Due to its capacity to operate under diffuse radiation, solar PV panels are becoming more popular all over the globe. As a result, it's critical to understand how PV panels react to changing weather conditions. Only 15–20 percent of solar irradiation can be converted into energy in reality, with the remainder being lost as heat. With every one degree increase in module temperature, PV module efficiency drops by around 0.40–0.65 percent. In hot dry regions, PV temperatures may exceed 80 degrees Celsius. As a result, constant attempts are made to improve photovoltaic efficiency. A photovoltaic thermal (PVT) system is a well-engineered solar cogeneration system that combines photovoltaic (PV) modules with solar thermal components to produce both energy and heat. The efficiency of PV cells decreases as their working temperature rises, which may be increased by removing the heat with appropriate cooling. The waste heat extracted to cool the PV module may be used in a variety of heating applications, including crop and fish drying, textile manufacturing, building heating, and dehumidification.

The main benefit of hybrid PVT systems is that they provide two yields, namely electricity and heat, for a little additional cost and a fraction of the area.This is a great example of optimization since the negative effects of overheating the panel are reduced by extracting the excess heat and repurposing it for beneficial purposes. Micro-channel cooling systems, thermo-electric cooling systems, heat pipe cooling systems, mist water cooling systems, water film cooling systems, PCM [1].

All of these systems operate with various kinds of fluids and may be categorized using the following criteria: single phase or two phase, moving parts or no moving parts, generation or no generation, active or passive, working fluid utilized. The following are some of the most frequently utilized cooling systems: Micro-channel heat exchangers are the most common kind of confinement heat exchanger. This system is used in electronic cooling and features channels with a hydraulic diameter of less than 1 mm. They may be machined on the backs of microelectronic component sub-strates in integrated circuits, where the heat produced by the electronic components is pushed into the coolant. Thermoelectric cooling systems use thermoelectric devices, which are made up of two types of semiconductors: n type and p type. Thermally, the materials are connected in parallel, while electrically, they are connected in series. When there is a temperature gradient, the majority of carriers diffuse from the hot to the cold side, resulting in a voltage and current. An applied voltage pushes a current through the materials in the opposite effect, resulting in an efficient heat pump that cools one side and heats the other [2].

Heat pipes transmit heat from a source via the evaporation and condensation of a fluid. Heat pipes are effective heat transfer devices that can transport heat over long distances and are intended to have a low temperature decrease. Several researchers cooperated on the photovoltaic cooling application of heat pipes cooling technology. This technique has been explored for concentrator photovoltaic panels in particular (CPV)[3].

Water is the operating fluid in the Liquid PVT Collector. In recent years, many researches on this cooling method have been conducted. The use of water as the working fluid improves efficiency significantly, according to studies. The energy delivered to the water in the tubes via conduction is transmitted to the posterior surface of the panel. Tubes, channels, and spiral tubes are all possible forms for the sheet and tube arrangement. Depending on the cooling technology employed, cooling systems have different limits. Because the PV module must be physically connected to the thermal absorber in order to have a better heat transfer, one of the most frequent restrictions is the need for glue. As a result, the average stagnation temperature for unglazed PVT is 80 C, whereas it may reach 130 C for glazed PVT[4].

Raghuraman presented two separate one-dimensional models for predicting the thermal and electrical performance of PVT photovoltaic combined air/liquid PVT collectors, as well as some recommendations for maximizing the total energy gained from the collectors, such as selective absorber Optical premasters, distance interval of glass absorber plate, and thermal contact, two years later. Incorporated and tested a novel transparent hybrid a-Si PV/T in the hybrid unit. The findings indicate that simple and inexpensive hybrid systems with consistent photovoltaic and thermal efficiency may be built. According to a research on hybrid forced-air systems [5].

The system can only be autonomous for certain design parameters and flows. A flat plane booster reflector was added to a flat hybrid solar air heater to expand this research .A strong thermal contact between the photovoltaic element and the absorber plate is critical for achieving excellent thermal performance in a PVT collector. To join the two pieces, a coating of high conductivity glue is usually used. The thermal contact between the PV panel and the collector is assessed using various materials and application methods. It was discovered that the PV panel's power output improved by 10% above the original design. More sophisticated methods, such as laminating together all of the components, may be utilized. In compared to previous PVT approaches, the experimental results revealed a substantial improvement in both thermal and electrical performance. Using pc-Si PV cells, the thermal and electrical efficiency at zero decreased temperature was 79 percent and 8.8 percent, respectively a non-contact situation a photovoltaic-thermal collector, which comprises of a PV panel separated by a traditional sheet and tube solar thermal collector. The thermal efficiency of the non-contact type system surpasses that of the contact type collector at higher input temperatures when PV transmissivity is high (> 0.75) [6].

The average yearly efficiency of photovoltaic power generation improved from 2.8 percent to 7.7 percent using a hybrid system, according to Kalogirou. The economic study revealed a 4.6-year payback time. When a photovoltaic panel was combined with a solar air collector, discovered that the electrical efficiency improved from 8.6 percent to 12.5 percent. According to the numerical model created by Siddiqui and Zubair, hybrid collectors are more beneficial in regions with high solar radiation and ambient temperature, such as those prevalent in the Middle East. Another benefit of PVT is the low cost of production. As a result, the energy payback time for PVT collectors was shown to be much lower than for conventional collectors.

2. DISCUSSION

2.1. Application:

The number of transparent coverings that may be utilized in a sheet-and-tube arrangement has been thoroughly examined. Single-glazed PVT was mentioned. A glazed collector produces more heat than an unglazed one. Nonetheless, owing to increased optical losses, its electrical output is decreased .It was also discovered that the effectiveness of exegetics rises with the flow temperature up to a certain point. Maximum value of 13.36 percent for glazed and 11.92 percent for non-glazed the optimal flow temperature for unglazed PVT collectors is, 83.6°C and 38.8°C, respectively. Chow and his colleagues Chow took measurements in the open air on two comparable sites. thermosiphon PVT sheet-and-tube water collection systems in Hong Kong Kong is available in two versions, one glazed and the other unglazed.

Six factors have an impact. The effectiveness of a set of operational settings was assessed. The examination of the first law If any of these options is available; the glazed design is always preferable. The total energy output, or thermal output, must be maximized. However, an unglazed system is more beneficial for high values of PV cell efficiency, according to the energy study. The packing factor, water mass to collector area ratio, and wind velocity are all beneficial for a glazed system, while the increase in solar radiation and ambient temperature are not. The use of additional coverings Reflection causes further losses. Other materials may be used instead of glass. Polycarbonate, for example, is a lighter, cheaper, and stronger material. For example, polymethyl- methacrylate and polyvinyl fluoride may be used.

The front cover the use of glass, on the other hand, is the finest choice because of its excellent optical characteristics, UV resistance, and high thermal tolerance Between the PV laminate and the cover layer, there is an air gap.must be thin enough to take advantage of the insulating qualities of air, while also inhibiting convective fluxes and microbursts turbulence.

Photovoltaic modules are usually attached to an absorber.EVA is used to encapsulate the cells. However, there are a few exceptions. PV lamination using conventional EVA presents technological challenges. It may disintegrate at high temperatures in the presence of acetic acid over 80 degrees Celsius As a result; traditional PV laminates are unable to survive the test. Temperatures in glazed collectors that are typically functioning at a standstill between 120 and 180 degrees Celsius A new idea for a glazed PVT collector The development of a PV laminate using Sloane gel is under underway. Using a gel instead of an EVA lamination material has many advantages. features such as high temperature resistance, transparency, thermal dilatation stress adjustment, and favorable In a PVT collector, heat transmission from PV to heat exchanger [7].

2.2. Advantage:

Other designs have been examined in addition to the conventional "sheet and tube" kind of water hybrid collectors .By changing the arrangement of the various components, the performance was examined .Sheet and tube, channel, free flow, and double absorption were recognized as the four major kinds of PVT based on the water flow pattern and heat exchange technique..

It is self-evident that a shorter distance between heat production and heat collecting results in more effective heat transfer. In the channel idea, this is achieved when the liquid flows directly over or below the PV cells.

The fluid absorption spectra should be sufficiently distinct from the PV absorption spectrum in channel PVT collectors. The inclusion of a second glass cover makes the assembly bulky and brittle.

The PV module may be transparent or opaque, with a black heat absorber underneath the channel. In comparison to a wide channel, this shape is more adapted to resist water pressures in the channels. In this arrangement, the absorber's "box channel" structure is used. Sandiness and Rested utilized this design to enhance heat transmission to running water by filling the square-shape box-type absorber channels with ceramic granulate. The findings for low-temperature water heating applications were encouraging. The BIPVT technique for facades uses a channel design with liquid flow beneath the PV cells. The system not only produces electricity and hot water at the same time, but also enhances the thermal insulation of the building envelope, thanks to the employment of wall-mounted water-type PVT collectors. According to the simulation findings, there is an optimal water mass flow rate for achieving the required energy performance. They also looked at the yearly energy performance of a BIPVT water system in both natural and forced circulation modes as part of their research. Both types of operation were able to decrease heat transmission through the PVT water wall by 72 percent and 71 percent, respectively, when compared to a standard building façade. The payback time of the BIPVT water system was determined, and the economic benefit of the BIPVT water system was shown to be considerably superior to a standard BIPV.

2.3. Working:

The creation of theoretical and empirical models is an important technique in engineering for predicting the performance of solar PVT collectors, for example, across a broad variety of operating circumstances. These models may be used for design reasons once they have been validated. PVT collector analytical models are based on energy balance equations that take into account the necessary heat transfer modes and appropriate boundary conditions. Several software tools, such as EES or ANSYS Fluent, are available to solve the governing equations .EES is generic equation-solving software that solves a number of non-linear algebraic equations at the same time. In a PVT collector, there are many different kinds of flow pathways.

PV cells above an absorber plate block incoming radiation, resulting in a decrease in energy conversion to usable heat, as many studies have shown. Created a model to investigate the performance of a heat pipe PVT system and utilized it to do parametric tests on a variety of parameters, including Pf. By raising Pf from 0.7 to 0.9, the temperature of the solar cell was reduced. Found that although a larger packing factor improves PV efficiency by approximately 3.5 percent, it degrades thermal efficiency. Garg and his colleagues using a computer model investigated the performance of a direct forced flow hybrid system for residential hot water generation. The usable heat contained in a tank was used to obtain the entire thermal energy. They came to the conclusion that raising the packing factor from 50% to 100% improved overall daily efficiency. The ratio of absolute total thermal plus electrical energy to total sun insulation was used to calculate efficiency. Dubai and Tiwari created a thermal model for a PVT solar water heating system and tested it for Pf = 30.56 percent, 50 percent, and 100 percent. Because PV cells are encased in glass, the PV modules were used to replace the glass cover on the collector's water intake side. With the rise in the area covered by PV cells, there was a reduction in thermal efficiency. Analyzed the hourly fluctuation of cell temperature and solar cell efficiency over the course of one day to combine and compare the findings. Compared the thermal and electrical efficiency of a photovoltaic-thermosiphon collector system with various packing factors of 0.50 percent and 100 percent using an experimentally verified numerical model. For the absorber, a box channel structure was constructed from a number of extruded aluminum alloy modules [8].

Two layers of EVA and tedlar-polyester-tedlar were used to encase the solar cells. The PV module's location was also assessed. The findings for thermal and electrical efficiency were greater when the PV module was installed in the bottom portion of the collector rather than the upper. Herrando found that a full covering of the solar collector with PV and a lower collector flow-rate improve both heat and electrical conversion accomplished with the PVT collector, while optimizing CO2 emissions reductions, with low solar irradiation and low ambient temperatures in the UK. A hybrid PVT system can provide 51 percent of total energy demand and 36 percent of total hot water demand over the course of a year with a completely covered collector and a flow rate of 20 l/h. The coverage value for power needs was only marginally greater than for a PV-only system (49 percent). Geometric features, environmental, and operational conditions are all discussed in section A physical concept for a hybrid flat plate collector with finned water channel was described by The effect of variables such as fin width to tube diameter ratio, input temperature, and mass flow rate on thermal and electrical efficiency was investigated using a parametric analysis. They found that increasing the fin width to tube diameter ratio from 1 to 10 reduces thermal efficiency by almost half. The flow rate and the temperature of the input fluid were determined to be the most significant factors [9].

The impact of a water storage tank's capacity was investigated further. A lower capacity increased just the thermal efficiency, but the electrical and total daily efficiency decreased. Other writers have also noted the presence of an optimal flowrate. Solar PVT modules incorporated into the building structure (BIPV/T) were investigated by .For various kinds of cells, the impact of mass flow rate on system efficiency was investigated. Although an optimal value was not determined, it was discovered that efficiencies grew until they reached a certain flow-rate value, at which point they stabilized. The electrical performance was found to be unaffected by the collector flow-rate (just a 5% fluctuation), while the hot water output was substantially impacted. As the volumetric flow rate rose from 20 l/h to 200 l/h, it decreased by approximately 35%. Optimal flow rate estimates for various absorber plate structures and PVT kinds Energy performance utilizing the second law method was utilized to investigate factors for improving the PVT hybrid collector. Aside from the presence or absence of the cover glass, the mass flow rate was shown to be a critical factor in energy efficiency. In terms of thermal and global exegetics efficiency, glazed PVT collectors have a rather low optimal flow rate of 2.3 g/s m2. Under a broad variety of environmental circumstances, photovoltaic conversion efficiency decreased with solar radiation intensity (3.6 percent/kW m2 at Ta = 20 C); whereas, the energy efficiency of PVT increased 3.6 percent per kW m2 (at Ta = 20 C). As a result, PVT's benefit in terms of solar radiation will be much greater. Due to the intermittent nature of solar energy, various algorithms and circuits were developed to determine the maximum power production from PVT collectors. Despite this, no control mechanisms have been implemented to monitor maximum power production from the PVT system. According, a PVT control method based on Artificial Neural Network (ANN) may be used to modify the Maximum Power Operating Point (MPP) by taking into account PVT model behavior. For a given irradiation and ambient temperature, an optimal mass flow rate is determined. The simulation results show a high level of agreement with the ANN outputs. The operating water temperature is another factor that influences the thermal and electrical performance of hybrid collectors.Low temperatures promote the generation of electricity from PV cells, while higher temperatures increase the value of thermal energy [10].

3. CONCLUSION

Clean solar power harvesting that is both efficient and cost-effective may be extremely important in meeting today's increasing energy demands and calming climate worries. It is anticipated that in the not-too-distant future, Solar energy will be cost-effective, making it possible to invest in and install solar systems even without government subsidies. As well as incentives this article gives a synopsis of current research.PVT thermal regulation methods are a kind of PVT. The investigation is still ongoing. The information above about PV cooling technique has been simplified to help you find what you're looking for. the unsolved issues and the future possibilities in this area The many Solar photovoltaic system applications include building integrated air PVT systems, solar air heating PVT systems, and liquid PVT systems.

Although there is a level, it is still restricted by the product dependability and availability. As a result, considerable research in the area of PVT is needed. Primarily in the design and manufacturing of thermal absorbers, as well as in material and component selection. Coating selection, energy conversion and cost reduction, performance testing, system control, and system liability some topics have only been researched on a small scale till now. Theoretical foundation despite the fact that considerable work in the PV/T research has been done, there are still some possibilities for future development available.

This technology includes the following: Developing novel practical, cost-effective, and energy-efficient technologies, such as PV/T based on PCM slurry, Improving the structural/geometrical characteristics of the structure PV/T configurations that are currently in use, Investigating the PV/long-term T's dynamic performance systems, PV/T system demonstration in actual buildings and feasibility analysis Comprehensive economic and environmental assessments that take into account Long-term measurements are used to account for the impact of climatic variables on the system's performance. Desalination and ply-generation systems, for example, required to be researched further. The use of heat pipes (with thermostats) is also an option. PVT solar collectors (because to their various configurations) have not been tested.PCM and thermoelectric systems have also been widely explored. additional potential future emphasis area in PVT technology several researchers have also suggested it. Despite the fact that PVT technology research and development work is under progress. over the past 30–35 years, the economic and political elements, as well as some technological problems, such as the issue of energy storage, have yet to be resolved. In a broad sense, it's been addressed. All of these efforts sought to provide the most energy efficient PV/T system feasible.

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