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The Hybrid Photovoltaic-Thermoelectric Generator Configurations for Energy Performance Improvement

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Abstract: Photovoltaic-thermoelectric generator is an integrated hybrid system, which enables optimal thermal management of PV and hence increases overall efficiency. The rise in temperature is one of the most challenging issues influencing the efficiency of photovoltaic systems resulting in significant thermal fluctuations affecting the hybrid system life span. PV cell cooling is a principal research aim that many researchers have focused their attention on. Thermoelectric generators used to improve photovoltaic efficiency are amongst the widely adopted thermal management systems. Photovoltaic cells convert the solar irradiance directly into electrical energy while the thermoelectric generator uses the heat not used by the PV, which results in parasitic loss of electricity. The current hybrid system, as in the spectrum splitting method, has shown promises of improvement. But, lack the practicality to be deployed to the mass market, which is due to the complex structure that is not feasible to be turned into a consumer product. At the same time, the direct method contributes to adding a little heat to the PV. Thus, reducing the total hybrid system efficiency, as such both lack the capacity needed for active cooling. However, with our proposed sandwich coupling method where the PV will be placed at the top of roofing shingle, the TEG under the shingle. The TEG will use heat not utilized by the PV, which cause excess heat in the PV cells to produce additional energy. At the same time, the shingle stabilizes the thermal fluctuation, thus Increasing total hybrid power output and efficiency. The system will provide a practical, real-life application. Our preliminary results show the significant improvement in power output generated with the double side heat sink. Furthermore, the result show a 22.66 % efficiency of the entire system in the sunny days in March 2021.

Keywords: Photovoltaic-thermoelectric generator, photovoltaic, thermoelectric, shingle, efficiency

1. Introduction

Energy is the mainstay of any economy [1]. It is one of the critical national development tools and has a significant impact on all aspects of our socio-economic development [2]. With a rising population and the level of gross domestic product (GDP), energy consumption is increasing daily. At present, 80 per cent of the global energy demand is from fossil fuel, and thus bring about the continuous diminishing of the fossil fuel reservoirs as such, it makes researchers shift their attention to renewable energy [3]. These sources of energy as fossil fuels are limited sources of energy that cause severe environmental challenges affecting the health of the people and the climate in general [4][3]. The world energy consumption would eventually go beyond conventional energy sources. Therefore, because of their outstanding benefits such as; low or no, emission, inexhaustible, reliability and the need to consider other sources like renewable energy with solar been the most readily available renewable sources.

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The maximum surface energy impeded by solar radiation is 7500 times more than the total yearly primary energy demand of 450 EJ [4]. In addition to solar thermal shown in Figure 1, Solar Photovoltaic has been one of the two essential technologies for solar energy. The conversion efficiency of PV cell is only about 5-10 % this is due to the excess heat on the PV cell from solar which, increases the PV cell operating temperature, thereby reducing its conversion efficiency [5][6]. Several cooling techniques have, therefore, been proposed for PV systems; among them, liquid and air-based PV cooling systems are the greatest innovative technologies with global practical applications [7].

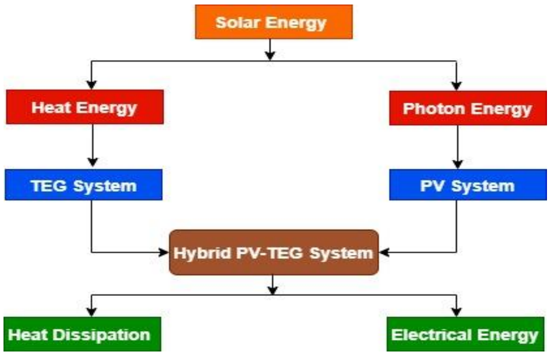

Fig. 1 - Solar Energy Conversion System

The efficiency of a PV cell is reduced by 0.25% -0.5% per degree Celsius based on the type of cell material used [8]. Thermoelectric generators (TEGs) are two-way converters of energy which can act as generators or coolers. Its convert electric power into heat, and vice versa. Thermoelectric converters have the advantages of gas-free, solid-state processing, enormous scalability, zero maintenance, long-term operating reliability and zero-emission,[8]. Material optimization and geometry of TEG are the two basic approaches for improving thermoelectric conversion efficiency [9],[10]. Combining photovoltaics and TEG devices would also result in an overall performance increase of the hybrid system [13]. Our preliminary results from the proposed method using a dual heat sink achieved a better efficiency of 6.5%. The overall efficiency of the system is increased by 5.47 x 10^{-3} %.

1.1 Photovoltaic Systems

A photovoltaic system is a set of interconnected electrical components that can generate electricity from sunlight and fulfil our daily energy needs without thinking about any time when there is no sunlight [14][15].

The photovoltaic effect is a method for generating voltage or electric current in a solar cell once exposed to sunlight. The PV effect was discovered in 1839 by French physicist Edmond Becquerel [14][16].

1.2 Temperature Influence on PV Cells

Some work on PV systems has been conducted to improve performance by applying efficient thermal management techniques. The efficiency of PV conversion depends primarily on the temperature of the solar cells; thus, efficient PV cooling is of utmost importance. It is evident from this that temperatures in PV cells affect cell performance, short-circuit current and open-circuit voltage [17]. Furthermore, Figure 2 illustrates the influence of temperature on the PV cell current-voltage (I-V) characteristics [18]. PV typically achieves better performance at lower values of cell temperature. The temperature coefficient of the PV cell is usually standardized at 25 ° C or 298,15 K when comparing different PV cells temperature [19].

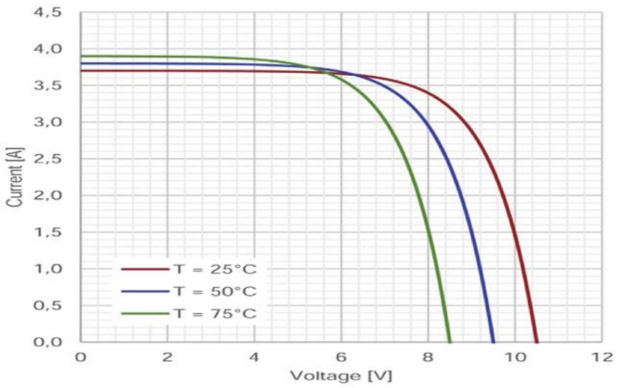

Fig. 2 - Temperature effect of a photovoltaic cell on the I-V characteristics [18].

This paper, therefore, presents a Review of the Configurations of Hybrid Photovoltaic-Thermoelectric Generators for Energy Performance Improvement and also introduce the readers to our proposed hybrid photovoltaic-thermoelectric generator sandwich coupling method. The shingle in this method will stabilize the thermal fluctuation between the PV and the TEG, thereby increasing the system output power and enhancing the efficiency of the hybrid system for practical, real-life application.

2. Thermoelectric Generator

Thermoelectric generators, use the Seebeck effect shown in Figure 3a, to generate electricity from heat. Once there is a temperature gradient (ΔT) across the thermoelectric couple composed of n-type and p-type semiconductor materials [20]. The mobile charged carriers located at the hot end (heat source) diffuse to the cold side (heat sink), thereby creating an electrostatic potential (ΔV). This method of generating potential differences due to temperature gradient is described as the Seebeck effect. Thomas Seekbeck was discovered in 1821 [20]. The Seebeck coefficient of TEG is expressed as [21]

$$\alpha = \frac{\Delta V}{\Delta T} \qquad (1)$$

3. PV-TEG Hybrid System

Integrating thermoelectric devices to photovoltaics will enable effective PV thermal management. Based on the PV-TEG configuration method, when combining thermoelectric generators with PV, the waste heat is utilized by the TEG to produce additional electrical energy. With proper configuration, the total efficiency of the hybrid system may be significantly improved. Several PV-TEG hybrid systems have been proposed to effectively utilize the solar energy's broad spectral region for energy generation. The PV-TEG hybrid system generates electricity by radiating with energy in the bandgap region of a PV. TEG converts the heat energy absorbed into electricity [22]. TEG can operate as a generator, so when used in a PV-TEG system, it can produce up to 10% more energy than a single PV solar cell, depending on the design, connections, and material of the TEG [23].

3.1 PV-TEG Hybrid System Modelling

The total performance of the PV-TEG hybrid system is the sum of the individual efficiencies of TEG (ηteg) and PV (ηpv) and is given [13]:

$$\eta^{pv}/_{\text{teg}} = \eta pv + \eta teg = \frac{P_{pv}}{P_{in}A_{pv}} + \frac{P_{teg}}{P_{in}A_{pv}} \qquad (2)$$

Where P_{teg} and P_{PV} are the output power of the TEG and the PV cell. Whereas the PV cell input power is Pin and the solar cell, the area is A_{PV} . Equation (3) above applies to a more straightforward configuration of a hybrid PV-TEG with TEG and PV thermally connected, however, electrically isolated.

Taking into account the efficiencies of individual modules of PV and TEG as well as the thermal dissipator, thermal converter, optical collector, Opto-thermal converter, and thermoelectric converter, the output of the PV-TEG hybrid system is [13][24]:

$$\eta_{PV/teg} = \eta_{PV} + \eta_{teg} = \eta_{PV} + \eta_{opt}\eta_{ot}\eta_{teg}\eta_{diss} \qquad (3)$$

Where, η_{opt}, η_{ot}, η_{diss} represents the optical collector efficiency, Opto-thermal efficiency and thermal dissipater efficiency. The efficiency of the optical collector is:

$$\eta_{opt} = \frac{CP_{in}A_{opt}\tau_{opt}}{P_{in}A_{opt}} = \tau_{opt} \qquad (4)$$

Refer to (4) the optical concentration is defined as *C*, the optical collector aperture area as A_{opt} and either reflectivity or optical collector transmittance as τ_{opt}Depending on whether mirror or lens is used. τ_{opt} is usually expected to be≥0.9; hence, the optical collector is presumed not to consume power; therefore, it does not heat up. Accordingly, η_{opt} it is considered as independent of temperature. The efficiency of thermal dissipaters is given as:

$$\eta_{diss} = 1 - \frac{P_{diss}}{P_{steg}^{out}} \qquad (5)$$

Where electrical power needed to circulate the cooling, fluid is P_{diss}, and the electrical power output of the solar TEG is P_{steg}^{out}. If passive dissipation is considered then (P_{diss}= 0) while if the active dissipation is considered then, η_{diss}= 1. The equivalent PV-TEG circuit is in Figure 3.

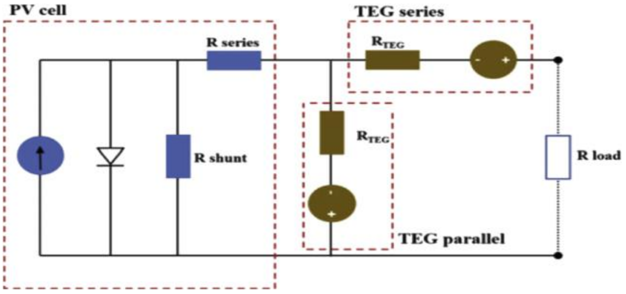

Fig. 3 - An electrically connected, PV-TEG equivalent circuit [13].

3.2 PV-TEG Hybrid System Coupling Methods

The solar spectrum is used more by the combination of photovoltaic and thermoelectric [25]. In theory, there are two approaches to developing a hybrid PV-TEG system [26]. Photovoltaic converts the ultraviolet and visible regions of the solar spectrum from 200–800 nm to electricity, meanwhile TEG converts the infrared region to electric power from 800-3000 nm [22]. There are two primary PV-TEG coupling methods [23][24].

3.3 Direct Coupling Methods

This method involved the attachment of TEG directly at the backside of the PV; the heat sink placed at the backside of the TEG, shown in Fig. 5. In this case, no splitter is used. In this system, the TEG absorbs 800-3000 nm of wavelengths, whereas 200–800 nm wavelengths are absorbed by the PV [17]. Furthermore, when using the direct coupling method, the TEG utilized the unabsorbed solar radiation from the PV as its input heat to produce additional electrical power, as shown in Figure 4.

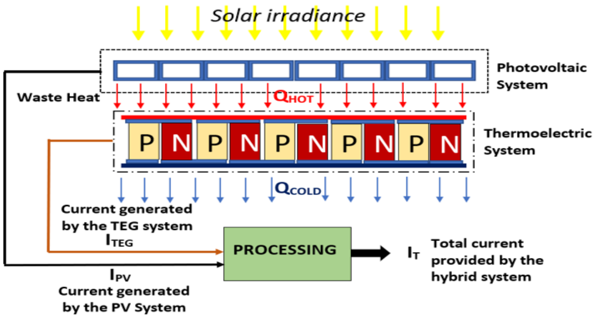

Fig. 4 - The schematic of the direct coupling PV-TEG hybrid system [18].

A few thorough investigations were carried out by Yin et al. [27][28][29] on optimum PV-TEG hybrid system design based on the direct coupling procedure. In the design, the real efficiency of the hybrid PV-TEG system was analyzed over 24 hours to assess the effect of solar radiation variability overtime on the PV-TEG hybrid system efficiency [30][31][32]. Initially, the temperature distribution was determined according to the hybrid system optimal efficiency; the maximum TEG thermal resistance was also measured, corresponding to the optimal temperature distribution of the hybrid system. Finally, the optimal configuration of the TEG was determined after the two preceding phases and the effect on the effectiveness of the hybrid system of the thermoelectric figure of merit and the cooling system convective heat transfer coefficient was examined. It was noted that TEG minimum figure of merit value could be used to carry out a CPV-TEG feasibility study and select the coupling devices.

Acut et al. [33] developed and examined a PV-TEG-WiFi Energy system for WSN use. The system developed a power combiner circuit that combines wind energy with a cross-coupled charge pump. 65 nm CMOS was used to simulate the system. According to the findings, when a load of 500 mW was applied, 1.69 mW was produced, resulting in a 69 % efficiency. Kil et al. [34] analyzed and presented a highly efficient CPV-TEG; they illustrated a hybrid CPV-TEG based on the direct coupling method using a conventional TEG module and a single-junction GaAs-solar cell to form a concentrated hybrid system. The experiment was conducted at a concentration of 50 suns. TEG was used to control the heat flow in the system. The hybrid system's overall efficiency improved by 3% as a result of the findings. Kil et al. came to the conclusion that the Peltier effect was critical in improving efficiency.

Performance of some of the reviewed PV-TEG system can be found in Table 1.

Table 1 - Summary of the Review Coupled PV-TEG

Author	Method	Finding
Li et al. [35]	i. Simulation with Crystalline Silicon PV Simulation with GaAs PV	11.07% for the PV-TEG and 9.5% for PV efficiency. 0.0085/K was the figure of merit, and TE load resistance was 0.75Ω. For GaAs, 0.0022/K was the figure of merit and TE load resistance of 1.60Ω
Zhu et al. [36]	Experiment and simulation using Monocrystalline Silicon.	The TEG added 648J as additional electrical energy for zero solar radiation period.
Cui et al. [37]	Experiment using single-junction GaAs and Bismuth telluride	Using Phase change material (PCM), 13.45% increase in the PV-TEG was obtained, the PV was also observed to have 13.43%.
Zhou et al. [38]	Experiment using DSSC and Bismuth Telluride	9.08% PV-TEG, 7.21% PV. The hybrid system performed better than the TEG with 725.5%. Increase in efficiency than the TEG.
Lamba et al. [39]	Simulation using Monocrystalline as PV and the TEG was Bismuth telluride	7.44% PV/TEG, 7.068% PV. The system achieved 595.5 mW power output.
Dallan et al. [40]	Experiment using Monocrystalline Silicon with Bismuth telluride	The hybrid system achieved 13.2%, the PV was 8.1%. The PV has the output power as 60.5 W/m^{2,} whereas the TE output power was 0.01 W/m^{2}.
Soltani et al. [41]	Experiment using Crystalline Silicon and Bismuth telluride with nanofluid as a means of cooling	3.355% increase in PV-TEG. The output power has an increase of 8.26%.

Li et al. [42]	Simulation using i. CIGS and Bismuth Telluride ii. Thin-film silicon and Bismuth telluride Polymer and Bismuth Telluride.	21.6% for the PV-TEG while 20.71% for the PV alone Concentration ratio was 200. 13.1% 12.89% Concentration ratio was 200. 8% 7.47% Concentration ratio was 180.
Liu et al. [43]	Experiment using Perovskite and Bismuth Telluride. Ice was used at the TEG cold side and 1.5 as the air mass	The PV achieved 9.88%.
Zhang et al. [44]	Experiment using Silicon	The hybrid system achieved wavelengths of 0.3–1.1μm absorption
A. Mohammadnia et al. [45]	Simulation and experiment	45.4 kW of total electric power output was obtained.

3.4 Spectrum Splitting Method

A splitter reflects the solar radiation at a specific wavelength for the spectrum splitting method; this can is shown in Figure 5. It also distinguishes between PV and TEG radiation used for energy conversion. TEG and PV are placed at the right angle to each other in this method. The TEG reflects the wavelength of the radiation, which is longer than the cut-off. In contrast, those shorter than the cut-off wavelength are transmitted via the spectrum splitter and absorbed by the PV [17]. Primarily, the TEG and PV operate independently to convert solar energy to electricity when applying spectrum splitting method; therefore, the TEG does not provide cooling for the PV or make use of the PV excess heat to convert additional energy.

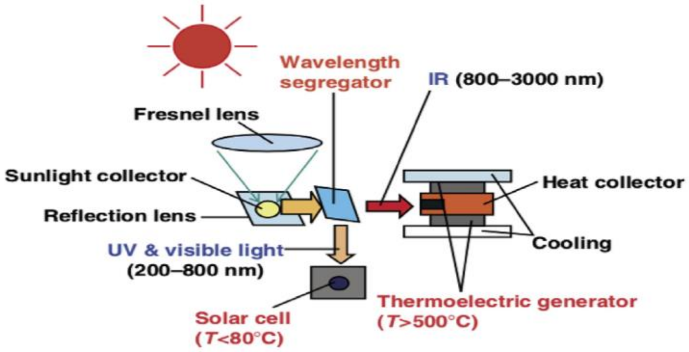

Fig. 5 - PV-TEG spectrum splitting method schematics [46].

Yin et al. [47], Suggested optimum configuration for a concentrated spectrum splitting PV-TEG to maximize solar energy distribution in a CPV-TEG splitting spectrum without sacrificing the optimal design status of the separate systems. The optimal operating temperature of the hybrid system was established, along with the cut-off wavelength. Additionally, the impact of the figure of merit of the coefficient cooling system was examined for thermoelectric and convective heat transfer. The authors proposed the thermoelectric configuration factor should determine the optimal distribution of distribution within the TEG. The optimum cut-off wavelength of the spectral splitter and the thermoelectric merit of the figure also have an inverse correlation.

In order to maximize solar energy in CPV-TEG spectrum splitting without sacrificing the individual's optimal configuration systems, Yin et al. [28] proposed an optimized configuration for the concentrated spectrum-splitting PV-TEG system. The results show that the thermoelectric ZT and the splitter's optimum cut-off wavelength are inversely proportional. Yan et al. [48](2018) investigated the efficiency of the PV-TEG spectrum-splitting system using computational simulation. The dimensionless current of the thermoelectric generator and the voltage of the solar cell were also investigated. At 30 and above concentrations, the results show that system performance improves by 2.67 % and 2.19 %, respectively.

3.5 Review of Experimental PV-TEG Approach

Several studies have been conducted to investigate the impact of various factors, such as the cooling system [49][50], system structure [51][27], concentration ratio [52][53] and contact resistance [49][39], in an effort to determine the best operating conditions for a hybrid PV-TEG system. The vast majority of studies focused on how solar irradiance affects the performance of hybrid PV-TEG systems. Their analysis indicated that when different PV cells are used, the concentration has a significant impact on hybrid system efficiency. Teffah and Zhang [54] found that when CIGS, polymer, c-Si, and p-Si PV cells with higher concentration ratios are used in a hybrid PV-TE system, the performance improves. Thermoelectric materials with ZT ≈ 1 on the other hand, improve overall system efficiency over concentration ratio. Through the use of experimental analysis, Mahmoudinezhad et al. [43], showed the transient activity of a concentrated hybrid solar cell triple-junction thermoelectric generator system. In this innovative research, the concentrated solar radiation was ranged from 0 to 39 suns with a solar simulator. The findings indicate that for a hybrid system containing PV and TEG, the TEG is an effective means of stabilizing the total performance of the hybrid system. Furthermore, the power generated by the TEG for solar concentration 39 suns and thermoelement length = l0.7 mm is 2.1 percent of the power generated by the CTJ. In addition, using numerical simulation, this ratio can be increased to 11.67% for thermoelement length =l 2mm. It has been suggested that combining TEG with the CTJ cell aids in the production of more stable power. Also, using more efficient materials with optimal geometry for the TEG can improve energy production by the TEG and compensate for a greater portion of the energy reduction by the CTJ, resulting in a more stable overall energy.

Taking into account the system structure, connection modes, total input energy, and device coupling characteristics, Yin and Xuan [55] presented an experimental optimization for a CPV-TEG system's operating conditions. The hybrid CPV-TEG was examined at various concentration ratios with concentrated photovoltaic (CPV) to examine the impact of the optical concentration ratio on the system's efficiency, according to the authors. The effect of TEG load resistance on power output was investigated in order to determine the desired performance characteristic features and the output voltage effect of photovoltaic systems. The effects of structural design and thermal resistance on the efficiency of the hybrid system were investigated. The TEG modules' parallel and series connections were also investigated. When the optical concentration was increased from 74 W/m2 to 217 W/m2, the results revealed a temperature difference of 28.9°C across the TEG, indicating a significant increase in TEG efficiency.

3.6 Review of Software PV-TEG Approach

Rodrigo et al. [56] conducted some theoretical study of both the efficiency and economic constraints of PV-TEG hybrid passively cooled systems. The study is aimed at the development of a thermal/ electric /economic system to examine the efficiency and economic weaknesses of the concentrated PV-TEG hybrid system passive cooling. Also, the order established made it possible to change the thermoelectric generator field. The findings revealed that to keep the cells operating temperature within reasonable limits, optimizing the region of the thermoelectric generator is necessary. Same as [57]. Shittu [58] used COMSOL 5.4 Multiphysics software to perform a three-dimensional mathematical analysis of four contact resistances in CPV-TEG. The resistivity between PV and TEG, TEG and heatsink, and TEG and thermal contact resistance was observed. In each case, 12 contact resistances were chosen to investigate the most critical one. Shittu et al. also investigated the optimal load resistance, thermoelectric leg height, concentration ratio, and heat convection within the system using a parametric optimization. The findings show that all contact resistances are important in determining the system's performance. The hybrid system's efficiency improves by 7.4% and 7.6%, respectively. Furthermore, Shittu et al. concluded that for effective energy harvesting, system thermal resistance must be minimized

The current hybrid PV-TEG systems lack the capacity needed to provide sufficient cooling and thermal fluctuation stability to improve overall power output and system efficiency. The numerical efficiency of a concentration-free PV-TEG system was investigated by [59]. During the research, they used an empirical approach, and the results showed that spectrum splitting in the hybrid system could achieve a peak efficiency gain of 1.8 %.

4. Our Proposed System

This paper would like to propose a PV-TEG hybrid sandwich configuration method of PV-TEG coupling with shingle roofing for real-life application. For this experiment, the National Instrument (NI-DAQ 9014) will be used for DAQ and data will be recorded, visualize using LabVIEW while MATLAB will be used for the analysis. Figure 6 shows the hybrid PV-TEG system's entire experimental setup. The photovoltaic system is installed on the shingle. The TEGs were installed on the shingle's back side, while the DAQ was used to monitor and records the system parameters. The experiment, will be thoroughly conducted for the PV alone, TEG alone and the hybrid system.

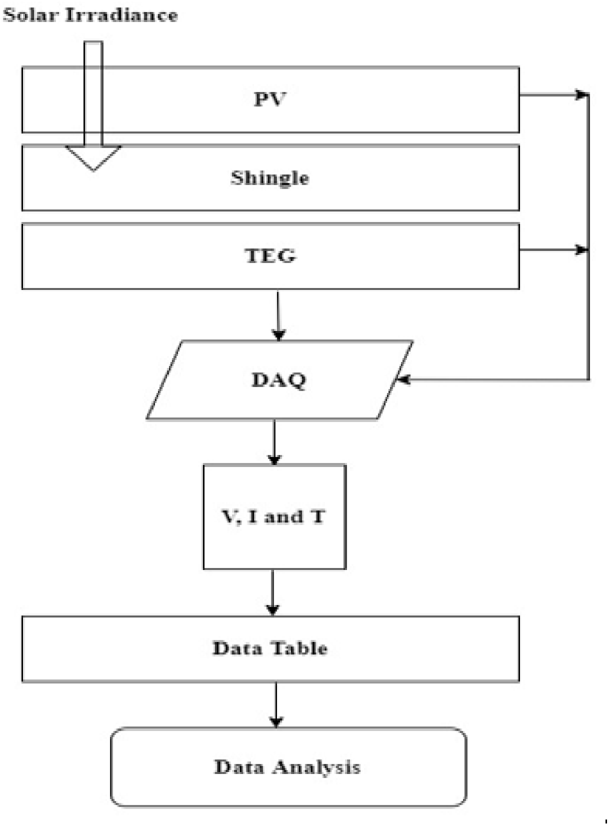

Fig. 6 - System experimental flowcharts

Form our proposed system; it is expected that higher efficiency can be achieved via experimentation. It has the advantage in scalability based on the roof side that can accommodate the sandwich configuration with the PV on top and the TEG at the bottom layer of the shingle. This method is shown in Figure 7 also to convert the shingle thermal heat generated due to the high solar intensity and the PV cells heat to electrical energy.

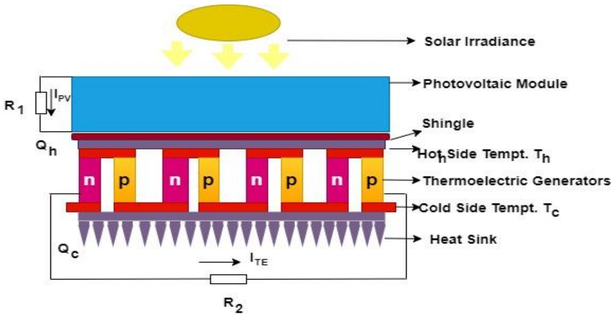

Fig. 7 – The Proposed Schematic of Sandwich Configuration Hybrid System

The shingle will serve the following purposes.

1) Convert sandwiched shingles between the PV and the TEG and acting as a thermal buffer that stabilizes PV and TEG thermal fluctuations
2) The TEG will also use the heat that is not utilized by the PV due to overheating and the shingle thermal energy to generate electrical power using Seebeck effect at the same time proving cooling to the PV for increase power output.
3) The performance of both PV and TEG will be improved, so also the system efficiency of the system will be enhanced while using air as a system coolant.

5. Preliminaries Results and Discussion

This section presents the preliminaries results and discussions for three different climate conditions in March and March 2021. From the preliminary results obtained the system indicate that the average PV alone has an efficiency of 18.16 % whereas the average TEG has 4.5 %; this individual system efficiency is low compared to the other renewable sources. However, the integration of the TEG and the PV which forms hybrid system can produce 22.66 % efficiency as against the results obtained from the literature consulted which shows through an experiment with the energy at 13.45% efficiency by Cui et al. [37] while 21.6% using simulation by Li et al. [42].

Table 2 show the average electrical power and efficiency variation in March 2021. The experimental findings in the rainy, cloudy and sunny of PV, TEG, and PV-TEG hybrid system electrical power is 129.76 W, 0.4 W and 149.62 W with corresponding efficiencies as 10.17 %, 3.1 % and 13.27 % for the rainy days respectively, in the cloudy days, the system produced 102.67 W, 0.13 W and 107.55 W with the corresponding efficiencies of 4.45 %, 0.08 % and 4.53 % respectively. On the sunny days, the system also produced 137.98 W, 1.06 W and 178.16 W with the corresponding efficiencies of 18.16 %, 4.5 % and 22.66 %, respectively.

Table 2 – Average power and efficiency for March 2021

Days	Climatic condition	PV Power [W]	TEG Power [W]	PV-TEG Power [W]	ƞPV (%)	ƞTEG (%)	ƞPV-TEG (%)
10	Rainy	129.76	0.4	149.62	10.17	3.1	13.27
3	Cloudy	102.67	0.13	107.55	4.45	0.08	4.53
18	Sunny	137.98	1.06	178.41	18.16	4.5	22.66

The TEG system generated a maximum delta T of 2.16 ^{O}C and a voltage of 2.96 V on average. In addition, 0.065 V was generated by an average lowest delta T of 0.03 ^{O}C as shown in Figure 8 below. This clearly supported the Seebeck effect.

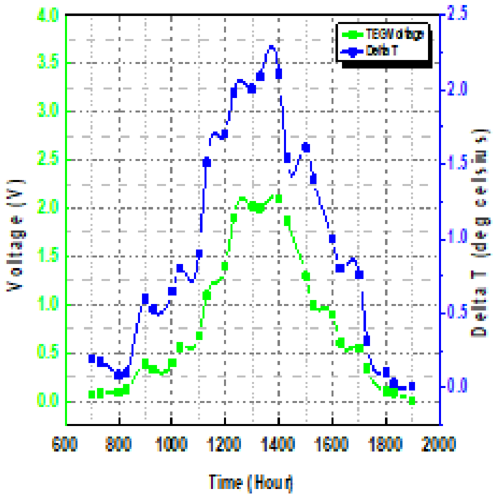

Fig. 8 - The average voltage generated across the TEG with the corresponding delta T

The average maximum power is 151 W at 11 am for the PV subsystem while 173 W W for the hybrid system as shown in Figure 9. The reason behind the above trend is due to the fact that a decrease in cell temperature causes a significant increase in PV voltage with a slight decrease in PV current, which eventually increase the output power and electrical efficiency

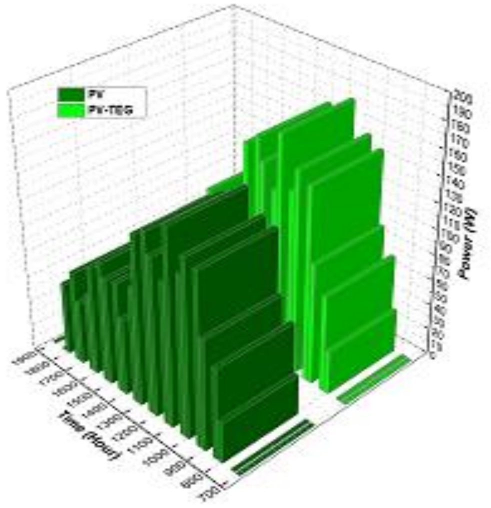

Fig. 9 - The average power generated by the PV alone and the hybrid PV-TEG system

Figure 10 shows the overall system efficiency. The efficiency is increasing in the morning until 3 pm and then decreasing till 7 pm. The average maximum efficiency of the PV subsystem for sunny days was 18.16 % at 11:30 am. The average maximum efficiency of the TEG subsystem for sunny days was 4.5 % at 01:30 pm. The average maximum efficiency of the hybrid system for sunny days was 22.66 % at 01:30 pm.

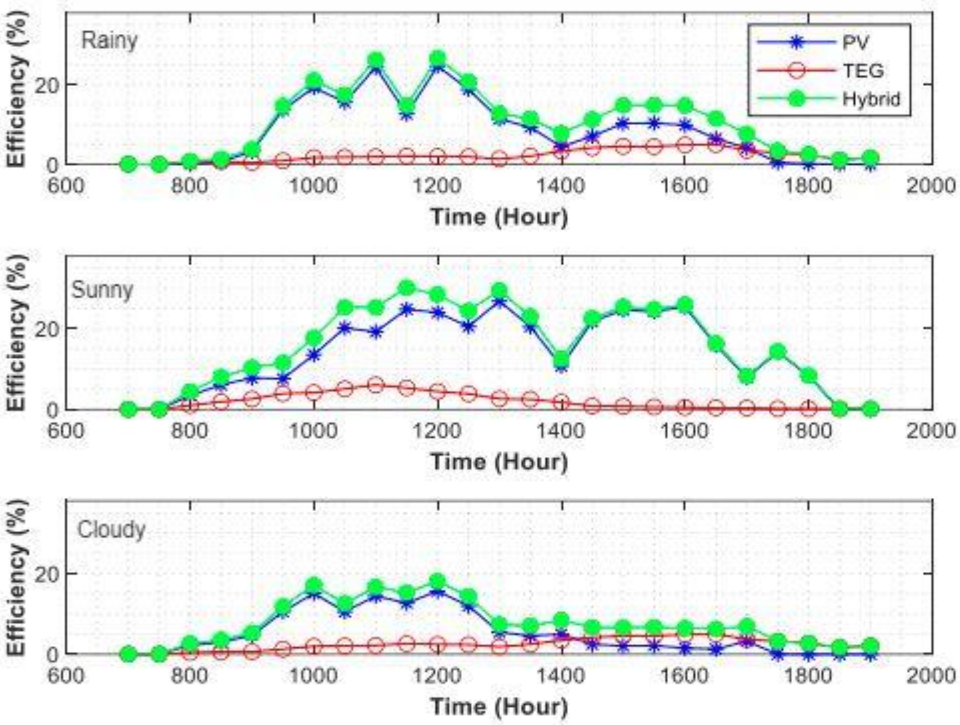

Fig. 10 - The efficiency of the PV, TEG and hybrid PV-TEG system showing the system behaviors in the rainy, sunny and cloudy days

6. Conclusion

Due to the global energy demand and the need to provide this energy through renewable means for a green and sustainable environment this review work became necessary. The photovoltaic-thermoelectric generators passive cooling is a thrilling research area; this is as of result of the application of passive cooling devices such as thermoelectric generators to significantly reduce photovoltaic temperature and increases the power thereby increasing the efficiency of the system. This paper describes and explains in detail the level of work performed in the area of hybrid Photovoltaic-thermoelectric generators system. PV-TEG gives an alternative to the commonly used PV-T systems. The system's focus is to improve the photovoltaic efficiency by decreasing the high temperature as well as converting it into additional energy production. This study, therefore, offered a broad view for most recent research aimed at enhancing the overall efficiency of the system. The study also provides information on important hybrid system research areas such as the implementation of PV-TEG to demonstrate its widespread use in multiple fields, other than electricity generation. Summary of the recently available journals concerning the hybrid PV-TEG was also presented. The preliminary results shows an enhanced system efficiency of 22.66 % in the sunny days in the month of March 2021. Lastly, with the proposed hybrid system, enhance efficiency is expected.

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