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Experimental Investigation on the Performance of Solar PV-TEC Hybrid System

B. Sahithi[1], D. Sai Anupama[2], G. Ganesh[3], D. Sai Kiran[4], D. Chanti[5], M. Sai Karteek[6]

[1,2,3,4,5,6]*GMRIT*

A B S T R A C T

The demand for clean and sustainable energy sources has led to significant advancements in the field of solar energy conversion technologies. Among these, Solar Photovoltaic-thermal(PV-TEC) systems have gained considerable attention due to their potential to simultaneously generate electricity and heat, enhancing overall energy efficiency. This experimental investigation focuses on evaluating the performance of a Solar PV-TEC system incorporating a thermoelectric cooler (TEC) module. The primary objective of this project is to assess the effectiveness of utilizing a TEC module in conjunction with a PV-TEC system to enhance energy generation and improve Panel efficiency. To achieve this, a comprehensive experimental setup has been designed and constructed, featuring a solar panel integrated with a TEC module by taking the values of the voltage and current with respect to the time. we will be comparing the values of the Preliminary results indicate that the integration of the TEC module with the PV-TEC system contributes to improved thermal management, resulting in a more stable electrical output and enhanced overall energy efficiency. The TEC module helps maintain the photovoltaic cells at an optimal operating temperature, thereby reducing temperature-related losses and prolonging the lifespan of the solar panel. This project's findings hold promise for enhancing the performance and applicability of Solar PV-TEC systems, particularly in regions with fluctuating weather conditions. The results will also contribute valuable insights into the integration of thermoelectric technologies with renewable energy systems, addressing the growing need for sustainable energy solutions. Future research may explore optimization strategies and scaling up this technology for commercial and industrial applications, further advancing the adoption of clean energy sources. So, in this we will be comparing the efficiency 's of the solar -PVT with solar-PVTEC by comparing the values of the average temperature , voltage, current, power, irradiance. By taking 2 different materials silicon-bismuth and Berylium telluride and with 3 different angles 280,310,330 of the inclination of the solar panel.

Introduction:

Solar Photovoltaic-Thermal (PV-T) systems represent a promising avenue for harnessing renewable energy by simultaneously generating electricity and heat from solar radiation. These systems have garnered substantial interest due to their potential to enhance overall energy conversion efficiency and provide a sustainable energy source for a wide range of applications. One innovative approach to improving the performance of PV-T systems involves integrating thermoelectric coolers (TEC) into the system design. This research project aims to conduct an experimental investigation into the performance of a Solar PV-T system using a TEC module.The world is increasingly recognizing the need to transition from conventional fossil fuel-based energy sources to cleaner, more sustainable alternatives. Solar energy has emerged as a forerunner in this transition, offering a virtually inexhaustible and environmentally friendly energy source. PV-T systems leverage both photovoltaic and thermal energy conversion mechanisms to maximize energy extraction from incident solar radiation, making them a compelling solution for meeting the growing demand for clean energy

Environmental parameters affecting module efficiency:

There are various environmental parameters that have an effect on the solar panel. For example, sunlight, ambient and module surface temperature, wind speed, humidity, shading, dust, installation height, etc. Among several variables, key role-players are indeed solar irradiance and temperature.

Effect of solar irradiance:

The short circuit current is affected by the amount of photons absorbed by the semiconductor material and is thus related to the light intensity . The conversion efficiency is therefore fairly constant in such a way that the power output is usually associated with the irradiance, but the efficiency is reduced if the cell temperature rises. The open-circuit voltage varies only marginally with the light intensity.

Effect of ambient temperature:

The VOC decreases so much with the rise in temperature of the panel above 25 °C but short-circuits current, ISC, increases only marginally. The temperature effect on P.V. performance is identified as the temperature coefficient. The net result is a reduction in power output with temperature rise. The percentage of temperature coefficient indicates a shift in output as it rises or falls against the normal conditions of 25 °C.

Effect of dust/shading : The increase in temperature of photovoltaic (PV) module is not only due to the climatic environment (ambient temperature) but also to the problems of direct and indirect partial shading; several recent studies are of interest to our present research. The shading on the photovoltaic module can be caused by the projection of the shadow of an object installed far from the solar panel (example: tree or candelabrum of lighting, etc.) or caused by dust deposition, if this last is uniform throughout the photovoltaic module, it could imply a thermal runaway on the PV panel. Likewise, when partial, hot spots can be created on the P.V. module. Power loss due to partial shading and hot spots can be greater than 70% .

Effect of humidity :

The air humidity means the amount of water content in the air. The relative humidity is often used to indicate air humidity which is the amount of moisture in the air. According to several researchers generally, two conditions are considered to evaluate the effect of moisture. First, the effect of particles of water vapour on irradiance of sun rays and the second effect of humidity during entry in enclosed P.V. modules. As the temperature changes during the day, the relative humidity also changes accordingly. Humidity shows an inverse relationship with temperature.

Effect of wind:

It may not be a correct concept to say that solar P.V.efficiency is directly affected by wind velocity. However, it has a major role to play in P.V.generation. When the wind flows, basically, the temperature of solar cell drops. The wind cools the solar panels resulting in producing less vibration of the electrons so the electrons can carry more energy while moving to the upper state.

Solar P.V. Cooling techniques

- **Need for cooling:**

The change in surface temperature is influenced by external climate variables such as sunlight, wind velocity, moisture, atmospheric temperature and concentrated dust. Improvement of efficiency can be accomplished by reducing the operating temperature as it is more problematic to modify other parameters involved. Of example, in the construction of photovoltaic panels on the building facades, which are vertical and non-directional surfaces, solar radiation is an uncontrollable parameter. To make photovoltaic more efficient, by avoiding the issue of temperature rise, a variety of cooling techniques have been carried out and have been reviewed in a variety of various literature.

METHODOLOGY:

Material and Equipment:

- Solar panels
- Pelteir modules made of different materials (e.g., bismuth telluroide, silicon)
- Mounting equipment for adjusting panel inclination
- Voltage measuring instrument
- Heat sink and cold sink
- Electrical wiring
- Cooling fan
- Temperature indicator

Measurement Parameters:

- Solar panel output voltage
- Temperature at various inclinations (28º,31º,33º etc.)

Experimental Procedure:

We acquired two sets of Peltier kits for our project. We proceeded with the assembly as follows:

1. Begin by removing the square-shaped center layer from the foam sheet and use it to cover the gap where the Peltier module will be placed.
2. Securely attach this foam sheet to the heat sink using screws. Position the foam sheet so that it lies evenly on top of the heat sink.
3. Apply a layer of thermal paste to the Peltier module and affix it to the cold side of the heat sink. This can be visualized as shown in Fig-3.1 .

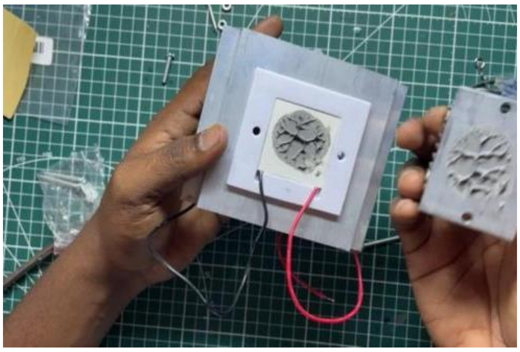


Fig-1: Applying thermal paste to the peltier module.

4. Fasten all components together using screws to ensure a stable assembly.

5. On the rear side of the heat sink, attach a cooling fan, and then affix a grill on top of it, securing everything in place with screws.

6. The assembly of the Peltier kit is now complete. Repeat the same procedure for the second Peltier kit.

7. Next, attach these assembled Peltier kits to the rear side of the solar panel. Additionally, connect a temperature indicator to the Peltier modules for monitoring purposes.

Finally, join the wires from the Peltier modules and connect them to the battery to complete the setup.

Construction of references

Caner Koc (2018) et al, investigated the possibility of solar-powered thermoelectric elements (Peltier) to harvest water from the atmosphere.Marati N(2019) et al, - investigated the possibility of manuscript proposes socio-commercial heat pumping system from interior to exterior and vice-versa based on the principle of Peltier effect. A.Kribus(2010)et al, investigated the possibility of Photovoltaic cells convert most of the absorbed photon energy to heat.Removal of the heat by thermal conduction creates a heat flux that is significant in concentrating photovoltaic cells subject to high incident radiation flux.Thualfaqir J. Kadhim(2020)et al, investigated the possibility of **a s**mall-scale prototype with one thermoelectric module was constructed to collect water from the atmosphere, and studied experimentally. Purusothaman Mani(2020)et al, investigated the possibility of electricity is one of the key issues for our day-to-day activities in today's technology-driven world. The fact that the renewable energy sources are depleting at a lightning-fast rate is clear to us all.

Research gap identified

1. Low Efficiency Conversion: One of the primary challenges is the relatively low efficiency of Peltier modules in converting heat into electricity. Researchers need to explore innovative materials and designs to enhance the conversion efficiency.

2.Temperature Gradient Optimization: Optimizing the temperature gradient across the Peltier module is crucial for efficient energy conversion. More research is needed to determine the ideal operating conditions, taking into account factors like solar panel temperature, ambient temperature, and insulation.

3.Integration with Solar Panels: Developing effective integration methods for Peltier modules with solar panels is a challenge. Researchers should focus on designing systems that are easy to install, cost-effective, and compatible with various types of solar panels.

4. Material Selection: Finding the right materials for Peltier modules is essential. Research should aim to identify materials that are both efficient and cost-effective for mass production.

5. Heat Management: Efficient heat management is crucial for the longevity and performance of Peltier modules. Researchers need to investigate advanced heat dissipation methods and insulation techniques to maintain a consistent temperature gradient.

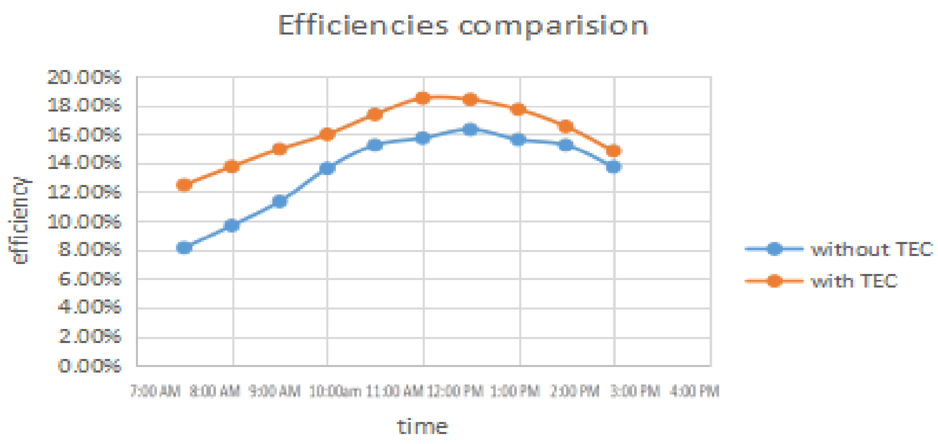
6. Environmental Impact: The environmental impact of Peltier module manufacturing and disposal needs to be considered. Sustainable materials and recycling processes should be explored to minimize the ecological footprint.

Results

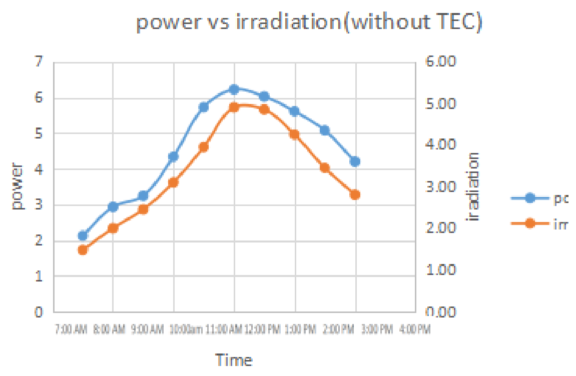
SILICON BISMUTH:

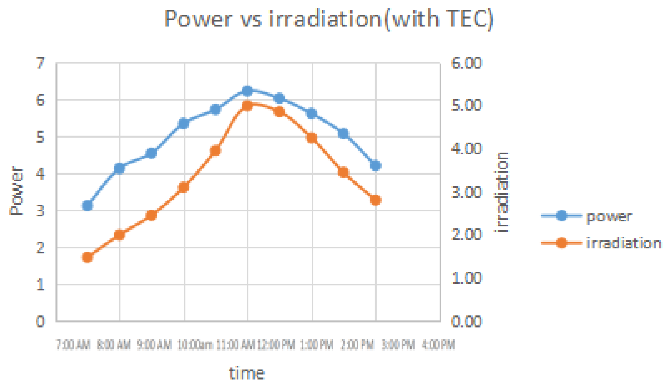
Comparision of 28^0 inclination of the solar panel with pelteir module(silicon bismuth material) setup :

At 28º:



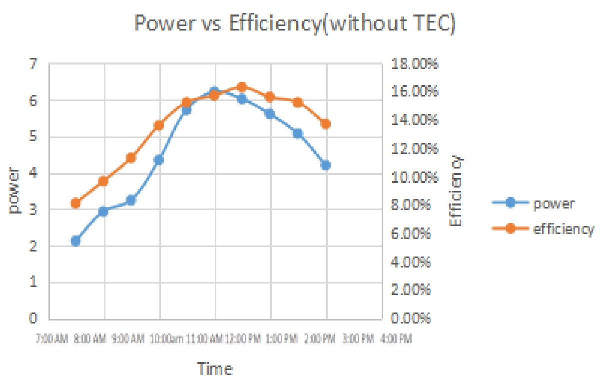
When comparing the efficiency of the panel with and without TEC gradually increased and the maximum efficiency obtained with TEC is 18.54%

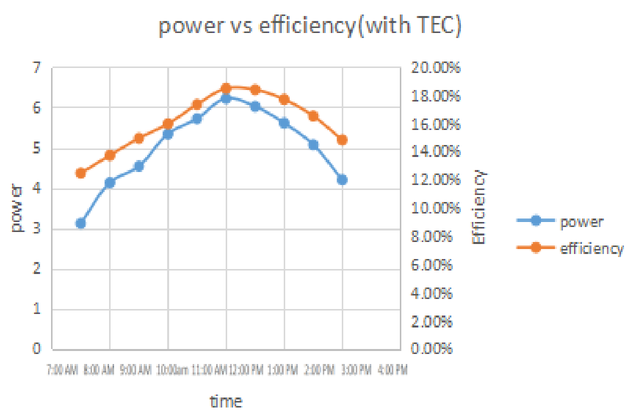




The power is slight linearly increased as the sun intensity gradually increases during the day time when the irradiation levels are at their highest. But there is a slight decrease in the irradiance when compared (with TEC).

- Solar panel exhibits the correlation between irradiation and the power output with respect to time , with the increased sunlight that lead to a gradual increase in the electricity as the day progresses.
- The power output of the solar panel increases with respect to time as the efficiency increases resulting in high electricity when integrated with



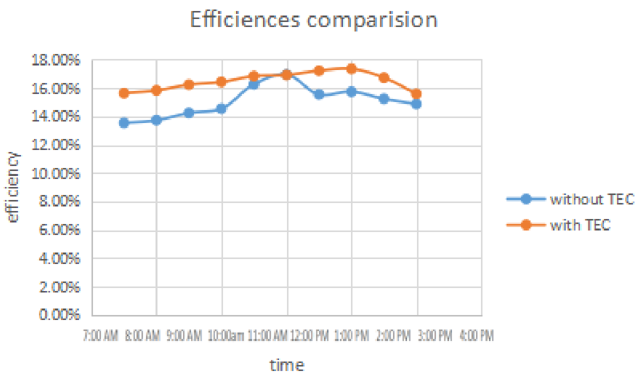


TEC .

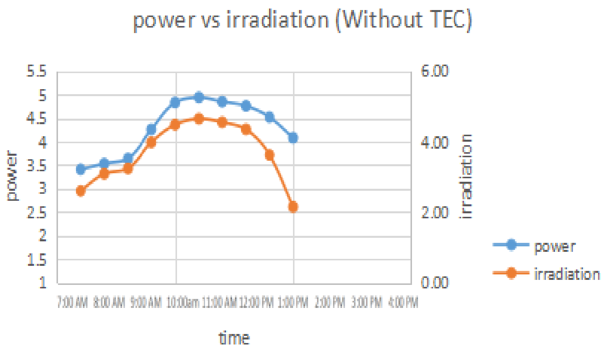
- There is a decrease in the power with respect to efficiency when the solar panel is not integrated with TEC.

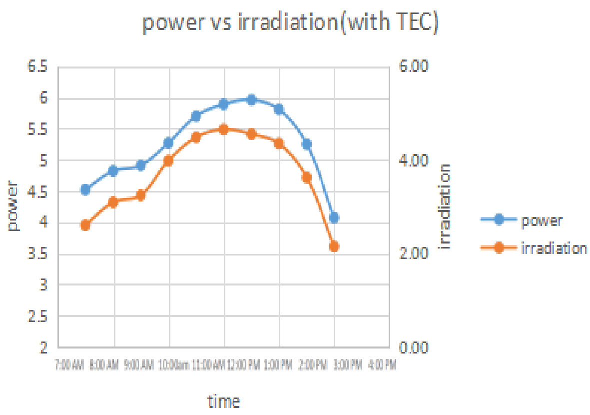
Comparision of 31^0 inclination of the solar panel with pelteir module(silicon bismuth material) setup :

At 31°:

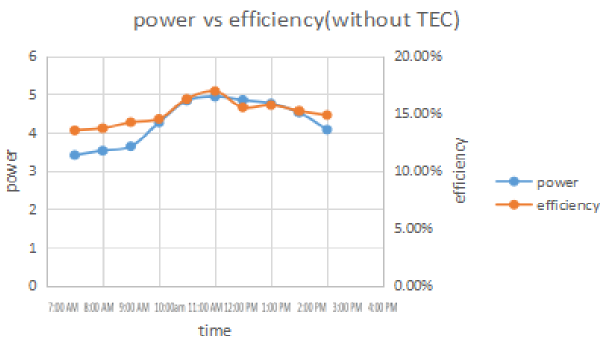


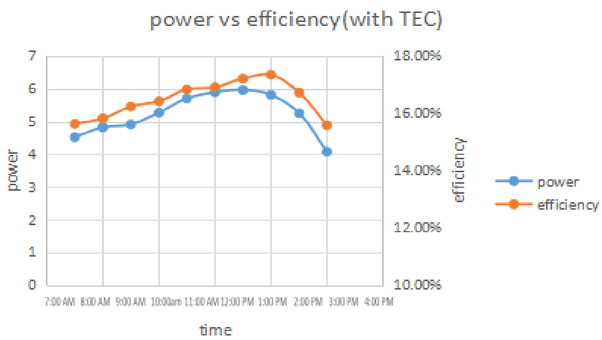
- The efficiency of the solar panel when integrated with the thermoelectric cooler (beryllium telluride) at 31 inclination has higher efficiency .The efficiency ranges from 13%-16% when compared without thermoelectric cooler i.e., 12%-14%.





- There is a slight increase in the power with respect to the irradiation when the panel is not integrated without thermoelectric cooler
- There is an increase in the power output with the increase in the irradiation when the panel is integrated with the thermoelectric cooler at 31 inclinatio

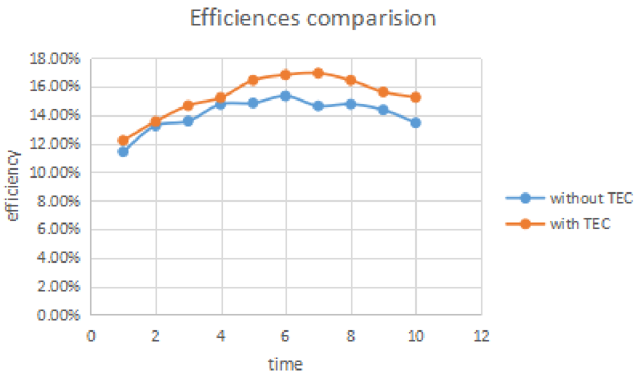




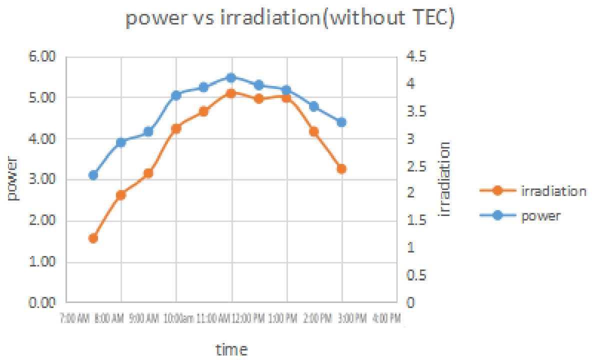
- The increase in the efficiency with respect to the power increases slightly when the panel is placed a t 31 inclination.
- The efficiency of the panel increases with the increase in the power output when the panel is integrated with the thermoelectric cooler at 31 inclination.

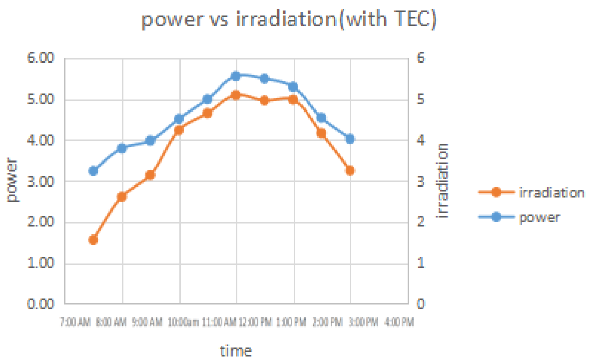
Comparision of 33^0 inclination of the solar panel with pelteir module(silicon bismuth material) setup :

At 33º:

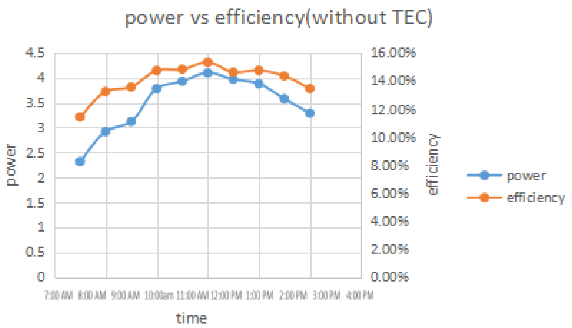


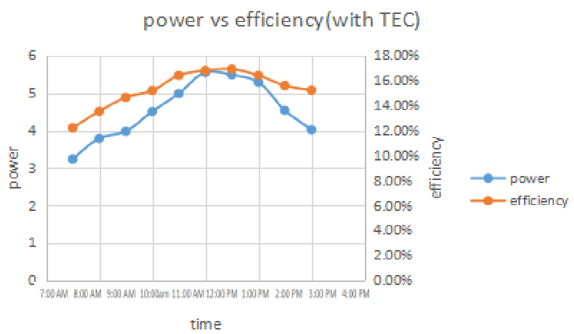
- The efficiency of the solar pv when compared with the thermoelectric cooler (silicon bismuth material) and without using the thermo electric cooler . The efficiency while using TEC ranges from 12%-17% and the efficiency without using TEC ranges from 11%-15% .





- The high power output results in the increase of the higher electricity with increase in the irradiation using (silicon bismuth material) at an inclination of 33 .
- The high power output results in the increase of the higher electricity with increase inn the irradiation using (silicon bismuth material) at an inclination of 33
- The efficiency of the solar panel increases as the power increases resulting in the high electric output .



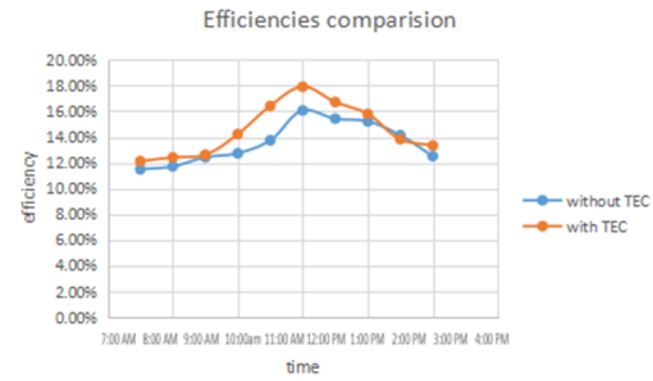


- The efficiency increases as the power output of the solar panel increases while using the thermoelectric cooler at an angle of inclination 33.

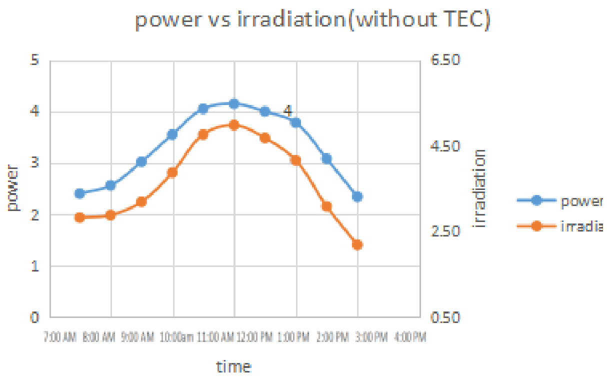
BERYLIUM TELLURIDE:

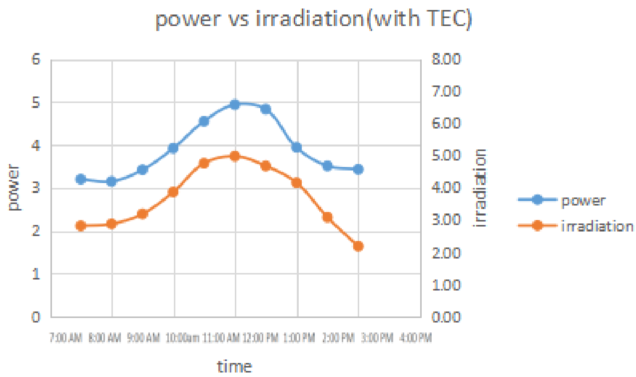
Comparision of 28^0 inclination of the solar panel with pelteir module(Berylium telluride material) setup :

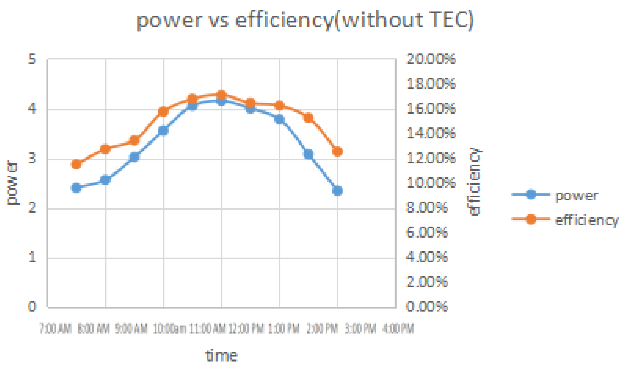
At 28°:

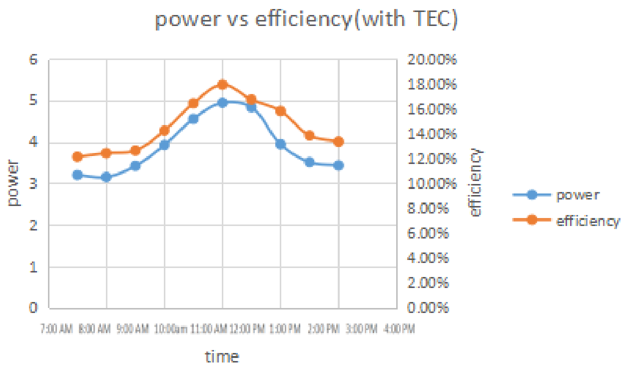


- When the solar panel is equipped with the thermoelectric cooler using an other material (beryllium telluride)inclined at 28 . The efficiency of the panel ranges from 12%-18% whereas the efficiency without thermoelectric cooler ranges from 11%-16%.Therefore the thermoelectric cooler increases the efficiency of the panel .
- The power output of a solar panel without a thermoelectric cooler increases when the correlation with the increase in irradiation.
- The power output of the solar panel increases with the increase in the irradiation due to the increase in the sun intensity when it is integrated with thermoelectric cooler.





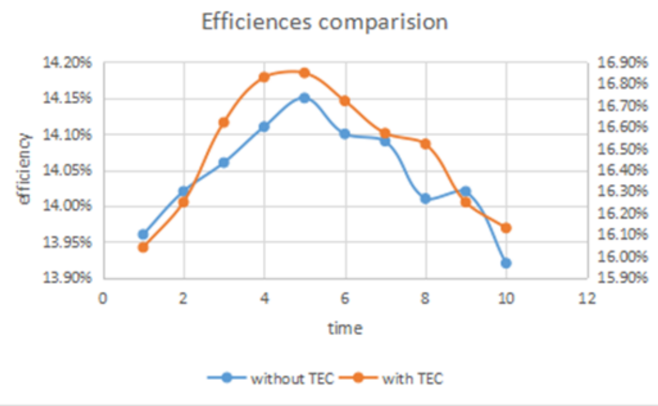




- The efficiency of a solar panel increases without the use of thermoelectric cooler , its power increases converting the sunlight into electricity .
- The efficiency of a solar panel increases with the increase in the power output , converting the intensity of the sun light into electricity when it is integrated with thermoelectric cooler.

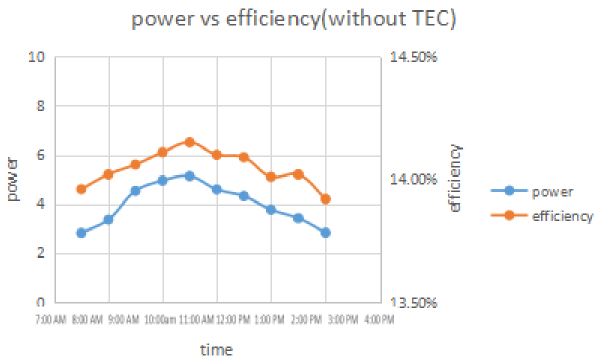
Comparision of 31^{0} inclination of the solar panel with pelteir module(Berylium telluride material) setup :

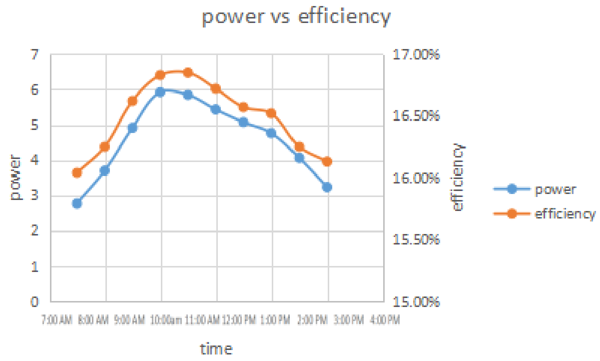
At 31°:

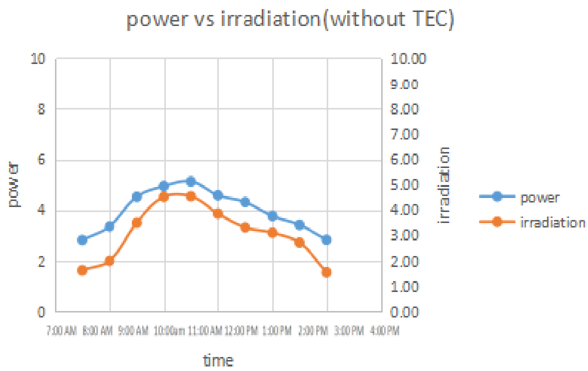


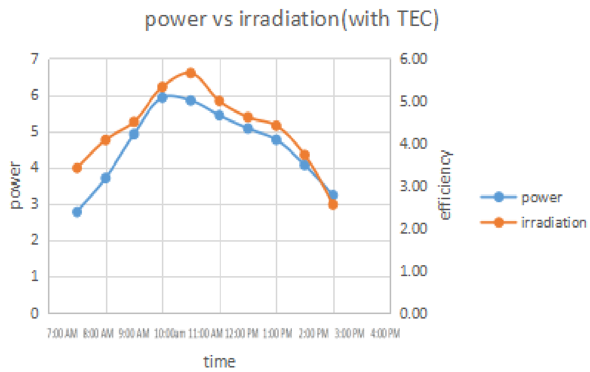
When we compare the efficiency of the panel while using the thermoelectric cooler .The efficiency ranges from 13.94%-14.23% while the There is a slight increase in the power output as the irradiation level gradually increase without using the thermoelectric cooler .

- There is an increase in the power with the increase in the irradiation using peltier module (beryllium telluride material)using thermo electric cooler at an angle of inclination of 31 .









- There is a slight increase in the power output as the irradiation level gradually increase without using the thermoelectric cooler .
- There is an increase in the efficiency of a solar panel with respect to the power output using the peltier module (beryllium telluride material) integrated with thermoelectric cooler to increase the efficiency .

Comparision of 33^0 inclination of the solar panel with pelteir module(Berylium telluride material) setup :

At 33º:

- When the solar panel is equipped with the thermoelectric cooler using an other material (beryllium telluride)inclined at 33º . The efficiency of the panel ranges from 17%-19% whereas the efficiency without thermoelectric cooler ranges from 13%-16%.Therefore the thermoelectric cooler increases the efficiency of the panel
- The power output of a solar panel without a thermoelectric cooler increases when the correlation with the increase in irradiation.
- The power output of the solar panel increases with the increase in the irradiation due to the increase in the sun intensity when it is integrated with thermoelectric cooler.
- efficiency of the solar panel without using the thermoelectric generator.It ranges from 13.9 here is a slight increase in the power output as the irradiation level gradually increase without using the thermoelectric cooler .
- There is an increase in the power with the increase in the irradiation using peltier module (beryllium telluride material)using thermo electric cooler at an angle of inclination of 31 .
- The efficiency of a solar panel increases without the use of thermoelectric cooler , its power increases converting the sunlight into electricity .
- The efficiency of a solar panel increases with the increase in the power output , converting the intensity of the sun light into electricity when it is integrate

Conclusion

In this experiment we had taken the average temperature values for about 3 months and had calculated power using voltage and current values which was taken simultaneously with respect to time by changing the inclination of the solar panel by taking 3 angles they are 28^0,31^0 and 33^0 also by taking two different materials -silicon bismuth and beryllium telluroide.We had taken irradiance values using pyranometer.and then we had calculated the efficiency of the materials by dividing the output power in watts to the solar irradiance (W/m^2) and had drawn the graphs of power vs irradiance with respect to time , power vs efficiency with respect time and efficiency vs time and comparing it with solar panel with TEC.By analyzing all the values we here by conclude that the efficiency of the solar panel increases by Decreasing operating temperature of the solar panel.Secondly, the combination of solar panels with Peltier modules enhances the adaptability of renewable energy systems. It allows for more consistent energy production in various environmental conditions, including extreme temperatures. This adaptability is particularly valuable for off-grid applications, remote locations, and regions with volatile weather patterns.In summary, solar panels combined with Peltier modules hold great promise for increasing the efficiency and versatility of renewable energy systems. While there are hurdles to overcome, this hybrid approach has the potential to play a significant role in our transition to a more sustainable and resilient energy future.

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