Solar cell and thermoelectric hybrid generators

T. Prapawan*

Bachelor of Education Program in Physics, Faculty of Education, Sakon Nakhon Rajabhat University, 680 Nittayo Road, That Choeng Chum, Mueang Sakon Nakhon, Sakon Nakhon 47000, Thailand

*Corresponding Author : prapawan_t@snru.ac.th, Tel&Fax : +6642970021

Abstract. This research presents the study of the production of hybrid systems co-generating electricity of solar cells and thermoelectric heat loss from solar cells to thermoelectric. The system used in the experiment consists of a 10 watt solar panel, size 350 mm × 250 mm × 25 mm, supported by metal plates for heat and installed with a thermoelectric 10 thermoelectric solar cell module installed, will install the thermal side of the thermoelectric under the panel solar cell. The cold side is cooled by the heatsink. The built system will experiment in open space. Notify all day the heat that is lost under the solar cell and supported by metal plates is used to generate electricity with thermoelectric. Which can convert the heat energy into DC power according to the seebeck effect. From the results of the experiment, it was found that the average heating temperature was 59.42 degrees celcius. The average cold temperature is 37.37 degrees celcius at 12:30 PM. The maximum temperature difference is 24 degrees celcius. The voltage is 0.98 mV DC. The current is 224.65 mA. The average power output from the solar cell is 5.36 W and The average power output from thermoelectric is 220.16 mW.

1. Introduction
Thermoelectric generators (TEGs) are solid state devices that produce electrical energy from temperature differences applied across the TEG. This generation technology was first introduced by Thomas Johann Seebeck in 1821 [1]. Seebeck reported that a thermoelectric potential energy could be developed in the presence of a temperature difference across two dissimilar materials. Various types of TEGs have been developed over the year to meet different power needed for different applications [2]. Hybrid solar energy conversion technologies always focus on the cascade use of incident broadband solar spectrum.[3-7]. Thermoelectric generator (TEG) can directly convert thermal energy into electric power, so it provides another way to use solar radiation and waste heat [8-11]. It is important to keep a significant temperature difference across the TEG under solar radiation [12]. Many methods have been developed to increase the heat flux on TEG with an optical concentrator [13] or to enhance the thermoelectric transport properties [14]. Reasonable numerical simulation and thermal design are also important to predict the generating performance [15] established a three-dimensional finite element model of multi-stage thermoelectric generator module for performance optimization [16]. The major advantage of hybrid the photovoltaic. Photovoltaic thermal (PVT) system is that they offer a two fold yields, namely electricity and heat with a little extra cost and half of the space. [17].

However, The hybrid PV/T panel collects two energies from solar radiation i.e., heat and radiant light. The PV panel converts photon (light) energy into electrical energy while the heat energy from solar radiation causes the reduction in PV panel electrical efficiency [18]. The electrical efficiency of the PV panel increases with reduction in the PV panel temperature [19]. There are many novel methods...
of adding TEG to the PV panel gives the concentrate & flat plate hybrid Photovoltaic-Thermoelectric Generation (PV-TEG) systems. [20]. The total amount of electrical energy generated from the sun radiation is slightly improved by using of PV-TEG system. In PV-TEG system, the most popular type is the concentrated type, because of the high amount of heat accumulation at one point [21].

In this paper, the study of the production of co-generating electricity of solar cells and thermoelectric heat loss from solar cells to thermoelectric. The built system will experiment in open space. Notify all day the heat that is lost under the solar cell and supported by metal plates is used to generate electricity with thermoelectric.

2. Materials and Methods
Experiments were conducted in July 2018 at Thailand. (latitude 17.192463 and longitude 104.093331) The inflow rate, solar radiation intensity, ambient temperature in these experiments. This research has been designed to include the selection of materials to create models for experiments to control the temperature difference under the solar cells supported by metal plates for heat gain. Including studying the feasibility of the system from studying the relationship between the temperature difference and the electrical energy generated by 10 thermoelectric modules with the structure.

From the design and construction of the power generation equipment Figure 1(a), the experiment will be conducted as follows: The experiment is to measure the power output from the temperature difference by connecting the thermoelectric number of 10 serial modules in the measurement experiment. The electrical parameters of the thermoelectric will use 10 thermoelectric modules to study the relationship between the temperature difference, voltage, open circuit. Electricity and power of the thermoelectric under the solar panel, 350 mm x 250 mm x 25 mm, supported by sheet metal, 420 mm x 660 mm x 2 mm, which has heat conductivity properties. To help get the heat and installing the thermoelectric sheet which was tested by connecting the thermoelectric number 10 serial module by heating the heat from the heat sink under the sheet metal designed. On the cold side, install the heatsink for cooling as shown in Figure 1(b). The temperature difference on both sides does not change, then let it cool down. Which the measuring instrument used is K type thermocouple by measuring solar panel temperature. The side that is exposed to thermoelectric both hot and cold sides. Including the ambient temperature measurement as well. The electrical measurement instrument used is the thermocouple data logger as shown in Figure 2, which collects data through a portable computer to create a comparative analysis of various electrical parameters.

![Figure 1. Design work structure of Solar cell and thermoelectric hybrid generators (a) Design work structure (b) Work structure](image-url)
3. Results and Discussion

Study and prototype of solar electric power generation equipment and thermoelectric electrodes produce electricity from heat generated under solar panels by using solar panels in the experiment. The thermoelectric will use the thermoelectric model SP1848-27145 where the heat is heated by heat loss under the solar cell and the metal plate. Install heat sink on the cold side.

In the experiment, there was a hypothesis that the solar radiation and solar radiation intensity Figure 3(a) were consistent on the experimental area. By collecting the experimental results during July 2018, experimenting at Sakon Nakhon Rajabhat University, the sun's radiation intensity with an average of 637.94 W/m² as shown in Figure 3(b).

The intensity of the solar radiation will change over time. This experiment will collect the intensity of the solar radiation at 8:00 AM to 17:00 PM by finding that at the start time of 8:00 AM, the intensity of the solar radiation is at 220 W/m² and the end time of collecting the results at 17:00 PM watch the intensity of the solar radiation is 320 W/m². For the maximum solar radiation intensity is equal to 1140 W/m² at 12:30 PM. The minimum solar radiation intensity is equal to the intensity of the solar radiation. 220 W/m² at 8:00 AM and the average day-to-day intensity of the sun's radiation intensity is 637.94 W/m².

In this experiment, the parameters of the solar panel temperature and the cold side of the thermoelectric temperature were studied. By measuring the temperature of 3 points under the panel to find the average value, found that the experimental results obtained as shown in Figure 4.
The relationship between the hot temperature of the solar panel with thermoelectric and the cold side temperature that is installed in the heat sink and the environmental temperature and the time of the experiment

The temperature difference of the hot side and the cold side has a similar average temperature difference at all times, as shown in Figure 4 the average temperature difference is 22.05 degrees celsius, with the time between 12:30 PM – 15:00 PM. The temperature varies the most. The temperature of this range will have an average temperature difference of 24 degrees celsius. It will be noted that the cooling temperature of the heatsink will decrease. The lower temperature is caused by the addition of solar panels to install the heatsink.

With the average electric current of the thermoelectric under the sheet metal with support equal to 214.92 mA, the maximum current value is 224.65 mA at 12:30 PM. The minimum current value is 180.35 mA at 8:00 AM, which is caused by a solar panel with a metal plate supported and a thermoelectric installed with a heatsink. Figure 5(a)

The average voltage of the thermoelectric electrode under the solar panel with a metal plate is equal to 0.92 V. The maximum voltage of the thermoelectric produced is 0.98 V. At 12:30 PM and the lowest
voltage will be at 0.82 V at 8.00 V. Therefore, it can be concluded that at 9:00 AM until 4:00 PM the voltage from the thermoelectric produced. Be high because during this period, ambient temperature will rise resulting in the thermoelectricity being heated by under the solar panel and there are metal sheets that support the temperature as well. Figure 5(b)

![Figure 5(b)](image)

**Figure 6.** Relation between the electrical power of the thermoelectric under the solar panel with a sheet metal supporting the time to conduct the experiment.

The average power of the thermoelectric under the sheet metal with support is 197.87 mW. The maximum power of the thermoelectric produced is 220.157 mW at 12:30 PM. The clock and the lowest power will be at 147.89 mW at 8:00 AM, as shown in Figure 6. Therefore, it can be concluded that at 8:30 AM until 17:00 PM power from the thermoelectric produced higher because during this period, ambient temperature will rise resulting in the thermoelectricity being heated by under the solar panels installed, the sheet metal also support higher temperatures.

**4. Conclusions**

The production of hybrid systems co-generating electricity of solar cells and thermoelectric heat loss from solar cells to thermoelectric. The system used in the experiment consists of a 10 W solar panel, size 350 × 250 × 25 mm³, supported by metal plates for heat and installed with a thermoelectric 10 thermoelectric solar cell module installed, will install the thermal side of the thermoelectric under the panel solar cell. The cold side is cooled by the heatsink. The built system will experiment in open space. Notify all day the heat that is lost under the solar cell and supported by metal plates is used to generate electricity with thermoelectric. Which can convert the heat energy into DC power according to the phenomena of according to the seebeck effect. From the results of the experiment, it was found that the average heating temperature was 59.42 degrees celsius. The average cold temperature is 37.37 degrees celsius at 12:30 PM. The maximum temperature difference is 24 degrees celsius. The voltage is 0.98 mV DC. The current is 224.65 mA. The average power output from the solar cell is 5.36 W and the average power output from thermoelectric is 220.16 mW.

**References**

[1] Gould CA, Shammas NYA, Grainger S, Taylor I. In: Proceedings of the 26th international conference of the microelectronics. MIEL; 2008. p. 329–32.
[2] Ahska R, Mamur H. A. Int J Renew Energy Res 2014;4:128–36.
[3] Yu, H.Y., Li, Y.Q., Shang, Y.H., Su, B., 2008. In: Proceedings of the 3rd IEEE Inter. Conf. on Nano/Micro Engineered and Molecular Systems, Sanya, China, pp.196–201.
[4] Leonov, V., Torfs, T., Vullers, R.J.M., Hoof, C.V., 2010. Journal of Electronic Materials 39 (9), 1674–1680.
[5] Van Sark, W.G.J.H.M., 2011. Applied Energy 88 (8), 2785–2790.
[6] Yang, D., Yin, H., 2011. Energy Conversion, IEEE Transactions on 26 (2), 662–670.
[7] Wang, N., Han, L., He, H., Park, N.H., Koumoto, K., 2011. Energy and Environmental Science 4 (9), 3676–3679.
[8] Amatya, R., Ram, R.J., 2010. J. Electron. Mater. 39, 1735–1740.
[9] Li, P., Cai, L.L., Zhai, P.P., Tang, X.F., Zhang, Q.J., Niino, M., 2010. J. Electron. Mater. 39, 1522–1530.
[10] Deng, Y.G., Liu, J., 2009. J. Renew. Sustain. Energy 1, 1–23.
[11] Chen, J.C., 1996. J. Appl. Phys. 79, 2717–2721.
[12] Hsu, C.T., Huang, G.Y., Chu, H.S., Yu, B., Yao, D.J., 2011. Appl. Energy 88, 1291–1297.
[13] He, W., Su, Y.H., Riffat, S.B., Hou, J.X., Ji, J., 2011. Appl. Energy 88, 5083–5089.
[14] Kraemer, D., Poudel, B., Feng, H.P., Caylor, J.C., Yu, B., Yan, X., Ma, Y., Wang, X.W., Wang, D.Z., Muto, A., McEnaney, K., Chiesa, M., Ren, Z.F., Chen, G., 2011. Nat. Mater. 10, 532–538.
[15] Xiao, J.S., Yang, T.Q., Li, P., Zhai, P.C., Zhang, Q.J., 2011. Appl. Energy 93, 33–38.
[16] Ju, X., Wang, Z.F., Flamant, G., Li, P., Zhao, W.Y., 2012. Sol. Energy 86, 1941–1954.
[17] Sahay, A., Sethi, V.K., Tiwari, A.C., 2013. Int. J. Current Eng. Technol. 3 (4), 1473–1479.
[18] Skopelaki E, Palyvos JA. Sol Energy 2009;83:614–24.
[19] Kalogirou SA, Tripanagnostopoulos Y. Energy Convers Manage 2006;47:3368–82.
[20] Makki A, Omer S, Su Y, Sabir H. Energy Convers Manage 2016;112:274–87.
[21] Lin J, Liao T, Lin B. Energy Convers Manage 2015;105:891–9.