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Theoretical and experimental study to determine the solar concentration limit with passive cooling of solar cells

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Abstract

This research is conducted to determine the limiting values of the geometric concentration when used with solar thermal system (thermoelectric generator) (TEG) to maintain desired hot and cold side temperatures for power generation. Experiments were conducted to determine the optimum solar concentration (aperture area/target area) using a thermoelectric generator sandwiched between the target plate and passive heat sink. A computer model is developed to solve the energy balance equations and find the optimum values for geometric concentration. It was observed that for the single configuration of heat sink and thermoelectric generator in a system, the trend of temperature difference between the hot and cold sides remain the same at different geometric concentrations. The optimum geometric concentration is determined for heat sinks in study. It is observed that with solar radiation intensity of 800 W/m2 and heat sink fin length of 0.15m the optimum geometric concentration is 13.

Keywords: Heat sink cooling; passive cooling; solar concentration; thermoelectric generator.

1. Introduction

In last few decades solar energy has shown a great potential in replacing the use of fossil fuel in producing electrical energy. Most of the research is concentrated on developing new technologies for conversion of energy from sun to

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electricity, and improving the performance of existing technologies. Concentrated solar systems are being widely studies in recent times, and have shown a great potential in improving the performance of existing systems as well as makes the design more compact. One of the technologies used with concentrated solar systems involve the use of thermoelectric generator (TEG) for conversion of the thermal energy from the solar concentrator to electricity. TEG works on the principle of Seebeck effect where two junctions of dissimilar metals are maintained at different temperatures that give rise to flow of current through those metals. The high temperature target area from solar concentrator system can be used as a source of hot side for the TEG, and the other side of TEG is maintained at lower temperature to generate electricity. To deal with this issue many passive cooling techniques have been designed and presented by researchers in the past [1-4]. Heat sink with fins is most widely preferred passive cooling technique that uses increased surface area for enhancing the heat transfer. A computer model is developed to determine the limits of the solar concentration to maintain the definite temperature difference across the hot and cold side of TEG.

2. Heat Flow Path

Incident solar radiation coming from the sun is optically concentrated using the Fresnel lens. The characteristics of square Fresnel lens manufactured from plastic having approximate thickness of 4mm were considered for design of a theoretical model. Optically concentrated solar radiations are directed to fall on the target area below the lens. The Geometric concentration at target could be determined simply by taking the ratio of the aperture area and the target area. Target area has a plate of the desired target area manufactured from high conductivity material. As shown in figure 1 Fresnel lens concentrates the incident solar radiation at the target plate. Thermoelectric generator is sandwiched between the target plate and the heat sink as shown in Figure 1.

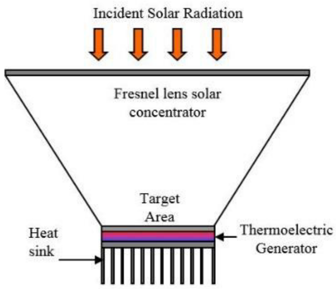

Fig. 1. Solar concentration system

The whole system shown in Figure 1 is further divided into 3 parts for the ease of heat transfer analysis. Incoming solar radiation (I) would fall on the Fresnel lens with an aperture area of (Ap). Aperture area of Fresnel lens will decide the total heat incident on the target area. This paper considers a square Fresnel lens that has a point focus. Geometrical concentration on the target area can be adjusted by varying the distance of target area from the aperture. Some of the solar radiation incident on Fresnel lens will get reflected back depending on the reflectivity of the lens. Some of the solar radiation will be refracted away from the target depending on the refractive index of the material of the lens. Manufacturing faults can also lead to some inefficiency in the Fresnel lens. Optical efficiency of the Fresnel lens is assumed to be 60% for this simulation[1, 2].

3. Discussion

The concentrated solar thermal system considered in this research has few parameters that need constraint depending upon the variation of thermoelectric generator considered in the system. Fixed parameter in this simulation will be ambient temperature, thermal resistance of TEG, optical efficiency of Fresnel lens and heat sink