Experimental investigation from different focal length of Fresnel lens on thermoelectric generators performance

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Abstract. When utilizing TEG (thermoelectric generator) module, it is important to know the performance of the TEG under focal length of a concentrating lens from energy radiation sources. To do this, incandescent lamp is used an artificial lights experimentally. Then, a design prototype of the TEG’s testing using Fresnel lens as optical radiation concentration prior to heat the TEG will be applied during the test. The test was conducted under laboratory scale using three power differences, 40, 75 and 100 Watt. White painted acrylic sheet is used as an envelope wall of the prototype to optimize walls heat radiation inside the design. Finally, The remo spectrometer has been using to measure the wavelength of each power. The result shows that the higher powers of the lamp, the bigger ranges are the spectrum of incandescent light with exception of 75 watt power. It could be more varieties spectrums of the higher power lights.

Keywords: Fresnel lens, artificial sun, TEG’s performance and light spectrum

1. Introduction

Thermoelectric generator (TEG) is a promising technology that converts exhaust heat into electrical energy due to the temperature difference between the hot and cold sides of the TEG module. The thermoelectric phenomenon is related to the production of electrical potentials from the temperature difference of the two materials in the p element (electron deficiency) and n (excess electrons) that is known as Seebeck effect as shown in Fig. 1.

Thermoelectric devices have the advantage of being easy to manufacture, easy to control and highly reliable. There is a moving part, but no voice and maintenance free. This thermoelectric shows the ability to operate for long periods of time and good performance along with the temperature differences that hit it. To obtain the temperature difference on both sides of the thermoelectric module it requires a radiation source of heat from various sources both the sun and other heat energy sources.

In this experiment selected heat source of incandescent and halogen bulbs are chosen. In order for the source of the lamp radiation to be optimally harvested by thermoelectric and increase the flux concentration, the use of Fresnel lenses becomes an option. The heat radiation passing through the Fresnel lens will heat the thermoelectric heat side, while the other side is kept at an ambient temperature. The higher temperature difference between the two sides of the TEG, the greater the output power generated.
Some studies have been implementing solar concentrators to increase the energy flux as it has been done. Li et al. designed experimental prototype of the concentration solar thermoelectric generator system. Heat pipe was used as cooling media due to highly temperature difference on both sides of the TEG.

In their experiment, reflector mirror have been applied to capture solar energy onto TEG from the Fresnel lens. Amatya and Ram [6] utilize a simple Fresnel lens in capturing solar energy with a heat sink as thermoelectric cooling medium. Researchers use new thermoelectric and thermoelectric types with high ZT values, namely ErAs: (InGaAs)-(InAlAs) and p-type (AgSbTe) x- (PbSnTe). While the new material was done thermodynamically with an efficiency analysis of 5.6%, and 3% for the commercial Bismuth Telluride (Bi$_2$Te$_3$) module.

Date et al. [7] presents the theoretical analysis and experimental validation on the transient behavior of a proposed combined solar water heating and thermoelectric power generation system. The system consists of concentrated solar thermal device that provides a high heat flux source for thermoelectric generators. Thermoelectric generators are passively cooled using the heat pipes that are embedded inside a heat spreader block.

Temperature difference across the TEG reaches 75°C with an open circuit of voltage 3.02V. Based on the use of concentrators on TEG’s above studies, focal length of Fresnel lens from TEG and wavelength spectrums are lack of concern. Therefore, this paper proposes such topic in laboratory scale at Heating and Cooling Lab. of Tadulako University.

2. Experimental set-up

In Fig. 2 the position of the bulb is within cover like a cone in order to protect heat losses surrounding. Heat radiation of the bulb is concentrated by the Fresnel lens and transmitted to the TEG. Focal length of the lens is adjustable up-down to see the effect of output power on generator thermoelectric. The amount of light radiation and both light and TEG temperatures were measured by Solar Power Meter TENMARS and digital thermometer, respectively.

Power generated by the TEG is noted with a voltmeter and its spectrum by USB Spectrometer connecting to a computer. Repeat test were undertaken on 3 bulbs power; incandescent light. For generator thermoelectric and USB Spectrometer can be seen in Fig. 3 and 4, respectively. The Spectrometer can see the wavelength of infrared (IR) spectrum.
Furthermore, the schematic of the testing rig can be seen in Fig. 4. Radiation of the lamps were going to Fresnel lens and light concentrating to TEG. Rig envelope is covered by black painted acrylic to protect other radiations from outside and increase heat convection. The measurement and observation parameters are as in Table 1.
Furthermore, after testing the system with artificial suns as heat irradiation, the system was tested under the sun leading to compare with the artificial lights. However, it can only be done for certain times for certain conditions due to configuration design obstacle. In fact, this kind of research design is for scale laboratory purposes. In terms of the power generated by TEG, same parameters in [8] and [8] will be considered in the completing of our proposed system.

3. Results and Discussion

3.1. TEG Performance

Testing results using incandescent lights proved that the lower focal length of Fresnel lens, the smaller is the output voltage of TEG. Observations using incandescent light sources indicate that the smaller focal lengths will be followed by decreasing the TEG output voltage, while the TEG temperature difference on both sides tends to fluctuate at 40 Watt (Figure 5), but increases with the thin figure at 75 Watt (Figure 6).

![Figure 5](image.png)

**Figure 5.** Focal length of Fresnel lens on TEG power output using 40 Watt of incandescent light

![Figure 6](image.png)

**Figure 6.** Focal length of Fresnel lens on TEG power output using 75 Watt of incandescent light

3.2. Light’s Spectrum

From the observation of the lights, they can be seen different wavelength in terms of ultraviolet, visible light and infrared spectrums, as described in Table 1. It shows that wavelength of 75 W bulb light has the best range of spectrum wavelength in which it starts IR from 588 nm, quicker than the two others power energy. This means that radiation illumination of the bulb power impinges on TEG leading to generate the temperature difference of it compare with both 40 and 100 W, respectively.
Table 1. Incandescent light spectrum for different power energy

| Wavelength (nm) | 40 Watt | 75 Watt | 100 Watt |
|-----------------|---------|---------|----------|
| Ultraviolet-UV/Vis | 429-598 | 429-588 | 426-608 |
| Infrared (IR)   | 598>    | 588>    | 608>     |

To procure the spectrum of the bulb lights, it needs a Spectrometer device that can provide the radiation spectrum of the light in nanometres (nm). For this research, the USB Theremino Spectrometer was applied following the instructions [9]. The spectrum range provides wavelength whether ultra violet/visible light or infrared. Unfortunately, the spectrum device could be able to figure out spectrum wavelength in the range of 400 and 700 nm. For TEG, infrared or near-infrared (600 nm >) is suitable to generate power energy depending on heat sources and operation temperatures of TEG.

Mostly researches on solar spectrum have been investigated in the form of numerical simulations in combining PV and TEG, not in the single module either PV or TEG itself. Among the combined PV and TEG can be seen in [10], [11] and [12]. Therefore, this single experimental on TEG’s lights spectrum in scale laboratory is a good start point for further investigating of hybrid TEG and PV.

Figure 7. Light spectrum of incandescent lamp using Theremino Spectrometer
It can be seen from the Fig 7, that the higher powers of the lamp, the bigger ranges are the spectrum of incandescent light with exception of 75 watt power. The more power illuminates the hot side of the TEG, the more temperature differences between the hot and the cold side and the better performance of the TEG. It could be more varieties spectrums of lamp lights beyond 100 Watts.

4. Conclusion

It is concluded that the less focal length of Fresnel lens from the TEG, the lower output voltage of the TEG. In addition to the lights spectrum, 75 Watt lamp indicates the best range of infrared that is suitable for the TEG. The red light spectrum (around 620 nm) indicates the NIR/IR wavelength for TEG needs leading to generating the power (voltage and electricity current).

5. References

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