

## The real-time Monitoring of TEG using the LabVIEW Technique for Green Energy Generation

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**Abstract** : The continuing rise in the cost of fossil fuels and their harmful effects on the environment have encouraged researchers to explore inward for an alternative source of energy. Through the Seebeck effect, thermoelectric generators (TEGs) have exhibited their ability to convert heat energy directly into electrical energy. Thermoelectric systems have emerged as a promising alternative to the existing technologies for green energy generation in the recent decade due to their unique characteristics. TEGs are also eco-sustainable, which operate quietly considering they lack mechanical systems or rotational parts. Therefore, they can be produced on a wide range of substrates, notably polymers, silicon, and ceramics. The real-time monitoring of the TEG devices is vital for determining the future utilisation of the technology and the green energy need. This project, therefore, presents the real-time monitoring of TEG using the LabVIEW Technique for green energy generation. The system monitor and records both electrical parameter and the temperature. The electrical data includes the TEG current, voltage and power, while the temperature data includes the shingle, TEG, and ambient temperature. The TEG was placed at the backside of the shingle under the photovoltaic panel of the test ring residential roof structure sloped at 30°. National Instruments (NI DAQ) unit was used as the data

logger. The results indicate a 10.99 V and 0.099 A at a temperature difference of 3.56°C, showing efficiency in the power output of 4.5 %. A thermoelectric generator is a solid and reliable technology used in a wide range of applications such as green agriculture, aerospace, medical, residential and industrial sector for energy generation that is free from emissions for a sustainable and green environment.

**Keywords:** Thermoelectric Generator, LabVIEW, Green Energy Generation

## 1. Introduction

Energy is a critical challenge for many nations, as alternative energy sources are needed to minimise reliance on fossil fuels [1][2]. Increased carbon emissions, the high cost of fossil fuels and the significant environmental effect are the major setback for the traditional means of power generation [3]. Electricity is now regarded as essential for a country's economic development, enabling social and economic prosperity. Furthermore, there is currently an energy crisis, which has revealed the limitations of energy production in meeting rising demand [4]. Approximately two-thirds of the energy generated in power plants is wasted as waste heat released via cooling towers. [5]. The primary reason for this is that most electrical power is generated by the gas-powered turbine, which burns fuel to produce thermal energy [5]. The thermal energy is then converted into mechanical energy inside the turbine, and the mechanical energy is then converted into electrical energy in a generator[6]. As a result, only around a third of the energy generated by the fuel usually makes it to the power plant's transmission system [7]. The potential to absorb thermal energy from these operations and convert it to electric energy would greatly improve power generation efficiency.

Furthermore, since fewer fossil fuels are burnt for the same amount of energy produced, the decrease of carbon emissions through reduced wastage would be helpful to the environment [4]. Currently, there is a lot of discussion concerning renewable sources of energy, and as a result, the electricity generated by waste heat has emerged as a potential renewable energy option [8]. Due to its various unique characteristics, thermoelectric generator (TEG) systems have received a lot of attention in waste heat recovery. TEG is a solid-state energy module that converts heat energy based on the Seebeck effect directly into electricity [6]. According to the Seebeck effect, electrical power is generated between two dissimilar devices when there is a temperature difference, as given in equation 1[9]

$$\alpha = \frac{\Delta V}{\Delta T} \quad \text{Eq. 1}$$

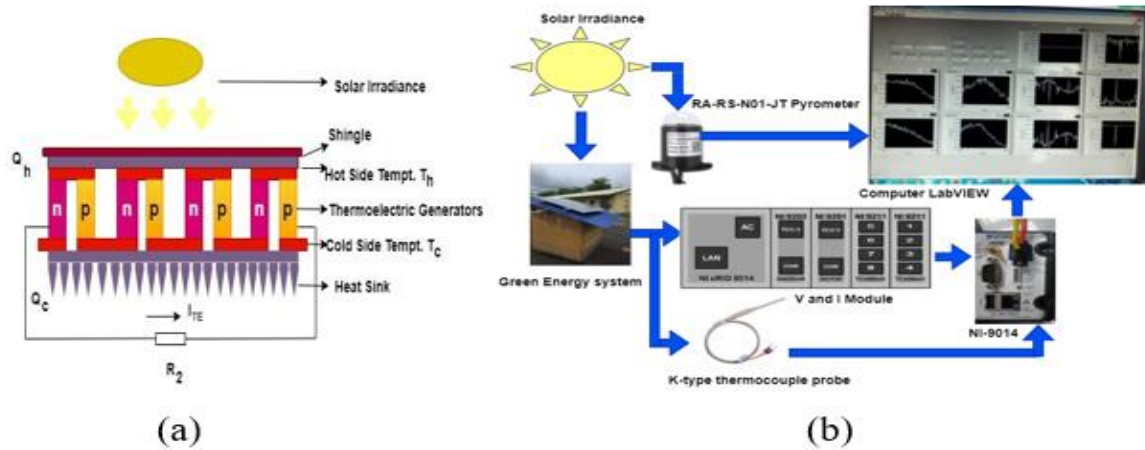
This project presents the real-time monitoring of TEG using the LabVIEW Technique for green energy generation with the following objectives

- i. To develop the TEG energy harvesting system for monitoring of the system parameters in real-time using LabVIEW
- ii. To evaluate the temperature gradient of the system for the overall improvement in thermal energy performance.
- iii. To analyse the current, voltage and power of the system for improved energy conversion

## 2. Materials and Methods

The TEG were placed at the backside of the shingle under the photovoltaic panel of the test ring residential roof structure sloped at 30°. National Instruments data acquisition system (NI DAQ) was used as the data logger. The system consists of one hundred and ninety-two (192) units of TEGs. The TEGs were divided into ninety-six, each connected in series and then paralleled for a single output and was thermally arranged at the rear side of the metal deck for proper heat conduction. A thermal paste was applied on both the metal deck and the TEGs backside to absorb extra heat flux and effective

thermal conduction. Heatsinks were placed at the TEG's cold junction for efficient cooling at the cold side. A 200 W monocrystalline PV module was placed directly on top of the metal deck test ring residential roof structure sloped at 30°. where the TEGs were mounted. The TEG's hot side temperature corresponds to the temperature of the backside of the PV; as such, it guarantees a substantial amount of temperature gradient for the voltage generation via the Seebeck effect by the TEG. As the temperature gradient was increased, a current was also produced. National Instrument (NI9014) was used as the data acquisition unit with a real-time interface provided by the LabVIEW software system. The NI9014 consists of a system of sensors as NI9203 for voltage, NI9201 as the current sensor and NI9211 with a thermocouple module for K-type thermocouple for the temperature measurements. The measurements are routed through the NI9014 to the computer's LabVIEW software, which processes and sorts the data into a data table. Figure 1(a) shows the schematic diagram of the system while Figure 1(b) displayed the LabVIEW software; through the graphical user interface, the data in real-time from the data acquisition via the Local Area Network (LAN) connection. The system is shown in Figure 1(b) was developed and installed for real-time monitoring at the Block B10 Laboratory, Universiti Tun Hussein Onn Malaysia (UTHM) in Parit Raja, Batu Pahat, Johor, Malaysia (1.8586° N, 103.0856° E) from 31st January to 28<sup>th</sup> February 2021.



**Figure 1: (a) Schematic diagram of the TEG system (b) Graphical diagram of the system**

The voltage  $V$  through the load resistance  $R_2$  is in equation (2)

$$V_2 = IR_2 \tag{Eq. 2}$$

Where:  $I$  is the current,  $R_2$  is the resistance of the TEG. The current ( $I$ ) is obtained in equation (3)

Equation (3) and (4) shows the TEG input and output power

$$P = IV = \tag{Eq. 3}$$

Where  $P$  is the difference between the thermal energy from the hot side to the cold side of the TEG [9]

$$Q_h = \alpha T_h I + K(T_h - T_c) - \frac{1}{2} I^2 R \tag{Eq. 4}$$

Where  $Q_h, Q_c$ , are the TEG heat energy from the hot to the cold side of the TEG,  $T_h$ , and  $T_c$  are the hot side and cold side temperature [10].

$$\eta = \frac{P - Q_h}{P} \times 100 \tag{Eq. 5}$$

Where  $\eta$  is the TEG efficiency [9]

### 3. Results and Discussion

The results were analysed and discussed in this section for more clarification and understanding. As shown in Figure 1(b) above, the LabVIEW displayed the real-time measurement of the temperature, voltage, current and power in words and graphical variation. This also corresponds to the analysis of the results in Figure 2 (a), (b), (c) and (d).

#### 3.1 Temperature performance

The average temperature variations during the experiment were observed to vary between 25 °C to 56 °C. the peak period was between 11 am to 3 pm, while the sunshine period was from 7 am to 7 pm. The highest temperature was 56.2 °C at 2:30 pm, and the lowest was 25.6 °C during the early sunrise and sunset. For the TEG hot side, the peak temperature was observed at 2 pm with 48.7 °C and the lowest at 25.5 °C. It maintained the same pattern for both the TEG cold side and the Ambient Temperature. The highest Delta T was obtained at 2 pm as 3.5 °C, which corresponds to the high power generation period as shown in Figure 2(a).

#### 3.2 TEG output voltage

Figure 2(b) depicts the average generated voltage variations for Feb. 2021 across the TEG during the experiment. The maximum voltage was obtained at 2 pm, during which the temperature gradient was 3.5 °C. The voltage varies between 0.5 V to 10.99 V. it is seen that as the temperature difference is increased, voltage also increased. This also verifies the Seebeck effect on the thermoelectric generator.

#### 3.3 TEG output power and current

Figure 2(d) depicts the average power generated by the TEG during the experiment. The maximum power was 1.5 W at a temperature gradient of 3.5 °C, a voltage of 10.99 V and 0.099 A, as shown in Figure 2(c) of the same month.

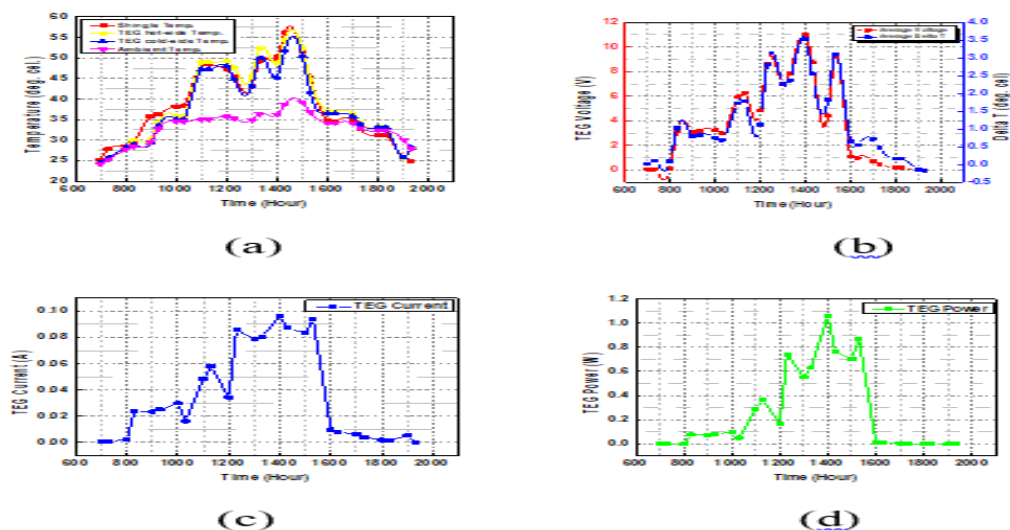


Figure 2: (a) Temperature of the metal deck, TEG hot and cold side and ambient, (b) TEG Voltage and delta T variation (c) TEG Current and (d) output Power variation

### 4. Conclusion

An experimental setup for the real-time monitoring of the thermoelectric generator system was developed using a LabVIEW interface under Malaysian weather conditions; the entire integrated

prototype was evaluated for real-time I-V and P characteristics measurements. Under normal ambient temperature, the LabVIEW shell was examined for clear daytime in February 2021. At a real-time rate, the electrical parameters and temperatures were monitored. The temperature variation during the day had the most significant influence on the system's performance. The developed system graphically displayed and recorded all variations and the electrical parameters of voltage, current, and power at the defined average time interval. The findings indicate a 10.99 V and 0.099 A at a temperature difference of 3.56°C, showing efficiency in the power output of 4.5 %.

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