Portable and Multipurpose Thermoelectric Generator Device

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***Abstract*— The researchers developed a multipurpose and portable thermoelectric generator that maximizes the waste heat generated from different sources to provide electricity that could power up low-voltage devices. Thermoelectric Generator (TEG) module converts heat energy into electric energy through temperature difference generated from both the hot and cold side of the module itself. This study used eight thermoelectric modules for the accumulation of waste heat to the hot side of the module and as for the cooling side; the researchers used a radiator as a medium to hold the cold substance. Based on the result of the testing, the device works best on waste heat sources from transport systems. For the cold side of the TEG device, cold water exhibits better performance in charging the batteries. Practically, the device can be used anytime and anywhere by anyone as long as the source can generate sufficient heat.**

Keywords*— *thermoelectric generator; radiator; waste heat; mobile devices

I. Introduction

Today's generation is continuously progressing with the development of many renewable energy sources. The use of electricity for lighting, medical devices and monitoring services, communication and electronic devices, and other major necessities can be crucial without electricity. According to the International Renewable Energy Agency, 2.36 million Philippine households in the off-grid areas of the Philippines are still not being able to use electricity in their homes. The use of renewable energy found in these areas can be of big help as a source of electricity. The Philippines' electricity generation is about 55%-65% renewable energy. This is evident in the fact that the Philippines has many ideal sources of natural energy. The primary sources of energy generation come from hydroelectric power, wind power, biomass and fossil fuel power, and the dominating solar energy power.

Recently, thermoelectric generator design has become widely used and has attracted the attention of many because this technology requires only minimal maintenance and is not weather-dependent. Such software can be used inside or outside homes or other commercial buildings. A TEG's working theory is the result of Seebeck. It is the temperature difference that causes electrons to pass between two metals or semiconductors in one direction, resulting in a continuous current to a full circuit. The voltage generated and the power are related to the Seebeck effect and the TEG's characteristics. Similar to other power generation systems, thermoelectric devices have different advantages. TEGs are branded attractive power generation systems because they are silent, non-moving solid-state devices, environmentally friendly, scalable from small to giant heat sources, and highly reliable.

As a source of energy, TEG primarily uses waste heat. It is cost-effective due to the free and abundant availability of waste heat. Waste heat is the unused heat (in the form of thermal energy) given by the surrounding environment. Often it is dissipated into the air, or large water bodies such as streams, lakes, and even the ocean. Some of the applications of TEG that have already been studied were the wireless self-powered sensors that can bypass the battery in places where there is no electricity [1], the transformation of solar directly into electricity, and on/off-grid systems [2], biomedical systems with discrepancies between human temperature and ambient temperature [3], telemetry systems with lower energy requirements [4], waste heat recovery in the internal combustion engines [5], electrical energy generation from overheated roads in the areas where no electric lines are available and use of warning systems [6], self-powered sensors [7], recovery of geothermal waste heat [8] and stove thermal generators [9]. TEGs are also commonly used in small, efficient applications instead of batteries [10]. However, these existing devices are developed only to generate electricity from a specific waste heat source and are stationary in such a way that they are only located at a specific location.

This study developed a TEG device that provides portability as long as there is a presence of waste heat to generate electricity. The device can be used to charge low-powered devices such as mobile phones.

II. Methods

With its hot side and cold side, the thermoelectric generator module harnesses the heat energy from a particular heat source through the hot side and the equipped radiator with a motor pump will sustain the needed cold temperature in the cold side. The difference in temperature between the hot side and the cold side is the key component of electrical power generation.

As shown in Fig. 1, the energy from waste heat is redirected to the thermoelectric generator module. The radiator is used to provide a cooling temperature for the overheated device. It is the main proponent of the cold side of the TEG device. The water motor pump is a device used to circulate water to provide cooling to the radiator. The generated power will go through the DC-DC converter to step down the voltage to 5V. The charging control module storage will regulate and charge the battery. Personal devices or external loads can be connected to the USB ports which are connected to the battery.

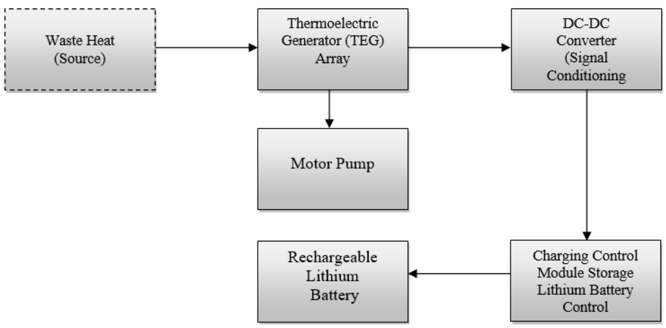

Fig. 1. The block diagram of the device.

The schematic diagram of the TEG device is shown in Fig. 2. The hot side is made up of eight (8) Peltier TEGs. The radiator absorbs the heat to lessen the impact of the hot side of the Peltier TEGs to balance the temperature. A water tank and a hose are connected to the radiator to provide circulation of water. A switch is also used to cut on or off the flow of electricity drawing to the water pump. A step-down USB port is connected to the TEG module to hold steadily the input voltage to 5 Volts. The power bank charging circuit (8) is used to charge the battery for electrical storage. The equipped USB ports connected to the power bank charging circuit are used for external loads to power up mobile devices.

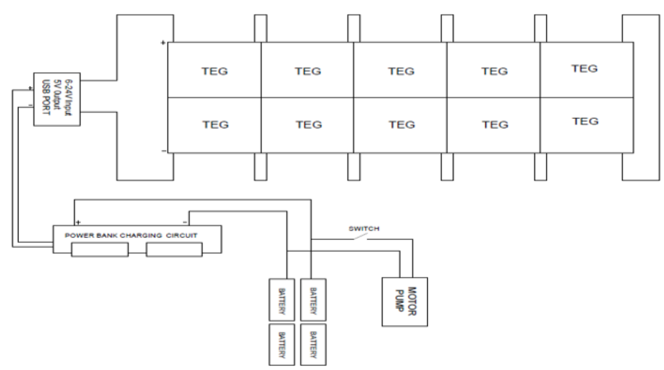

Fig. 2. The schematic diagram of the device.

III. Results and Discussion

The working prototype of the device is shown in Fig. 3, Fig. 4, and Fig 5. The thermoelectric generator modules are directly mounted to the radiator to balance the temperature difference. On the other side of the radiator, the water tank and the motor pump which provide circulation of the water and batteries are mounted. The connected power bank circuitry is placed at the back of the device to show the charging capacity of the battery. The equipped USB ports are found above the device. Alongside the power bank circuitry is the step-down USB port. The casing of the device is a plastic power supply box. The switch is found on the left side of the device which is used to cut on or off the flow of electricity drawn to the water pump. The device is lightweight and can be carried anywhere and at any given time.

Fig. 3. The perspective view of the device shows the bottom where the TEGs are attached.

Fig. 4. The perspective view of the device shows the side view where the switch is located.

Table I shows the voltage output based on the substance used on the cold side and the waste heat source used on the hot side. The cold substances used were tap water, cold water, and coolant while the waste heat sources were flat iron, BBQ grill, aircon, and motorcycle exhaust. The duration of the testing was for 15 minutes only. The percent charge of the battery was computed to show the increase in voltage. The initial battery voltage was the voltage before testing while the final battery voltage was the voltage after testing the device. The temperature change was calculated to determine how well the waste heat source and substance work in the device. The percent charged was also computed to determine how much charge had changed in the battery during the 15 minutes of testing.

Fig. 5. The perspective view of the device shows the USB ports for charging.

TABLE I. VOLTAGE AND CHARGING TEST

Trial	Hot Side	Cold Side	Initial Battery Voltage	Final Battery Voltage	ΔT (°C)	Percent Charged
1	Flat Iron	Tap Water	3.686	3.72	47	0.92
2	Flat Iron	Cold Water	3.671	3.729	55	1.576
3	Flat Iron	Coolant	3.441	3.487	49	1.34
4	BBQ Grill	Tap Water	3.691	3.691	40	0
5	BBQ Grill	Cold Water	3.769	3.805	52	0.95
6	BBQ Grill	Coolant	3.738	3.765	43	0.73
7	Aircon	Tap Water	3.677	3.677	16	0
8	Aircon	Cold Water	3.582	3.582	24	0
9	Aircon	Coolant	3.533	3.533	19	0
10	Motorcycle Exhaust	Tap Water	3.612	3.655	45	1.2
11	Motorcycle Exhaust	Cold Water	3.521	3.582	53	1.73
12	Motorcycle Exhaust	Coolant	3.612	3.663	48	1.414

The results show that the device performs well in charging the battery using cold water as the substance on the cold side regardless of what waste heat is used on the hot side of the TEG. It can also be deemed from the result that using the device in an air-conditioning unit will not yield nor change the battery charge. This is because the change of temperature is so low using this waste heat source. Based on the results, the waste heat source from the motorcycle exhaust produces the highest percent charged. This supports the claims of [11] on the usefulness of TEG when installed in motorcycle exhaust.

IV. CONCLUSION

In this study, the researchers were able to develop a portable and multipurpose thermoelectric generator for electricity production from waste heat. The device was able to provide the needed current and voltages for charging up the batteries. It is best used on waste heat sources in homes and transport systems.

For the improvement of the project, the researchers recommend a unit that can be able to monitor the increase and decrease in voltage, changes in amperes, difference in temperature, and percent charged and power. In addition, a higher quality specification for TEG and radiator to better gain voltage and current from small heat generating sources.

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