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Development of TEG Peltier Device for Heat Harvesting from 1.5 HP Split Unit Air Conditioning System

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Abstract

In today's world, recycling energy would be alternative in achieving green environment. Air conditioning shows the biggest energy consumption worldwide. Commonly air conditioning used to maintain indoor temperature. In Malaysia, split unit air conditioning system are famous for small area application. However, the heat release by condensing unit are wasted to the environment. Therefore, one peltier device using thermoelectric generator (TEG) module were develop in this experiment. The aim of this paper are to present the development of peltier device to harvest heat from condensing unit, hence convert it to electricity. The peltier device were sandwich among copper plate sizing 120mm x 60mm x 2mm. The copper plate were brazed at the discharge pipe of compressor and the other side of copper plate were attach to the heat sink where flow through by condensing water from evaporator. Six peltier were arrange respectively between copper plates. 3 case were monitor depended on the ΔT of cooling coil and condenser temperature. The maximum ΔT were observed at case 1, and simultaneously monitored voltage output for each peltier. The maximum 1.61V were collected from the split unit air conditioner after 30 minutes of operation with around 9-10 °C of ΔT. The application of TEG to harvest heat and turn into electricity shows the promising alternative for heat recovery. The current generated may useful for small scale used of electricity for household usage.

Keywords: Air conditioning, TEG, heat recovery

INTRODUCTION

Our dependence on energy resources have shown the increase by energy usage. Therefore, existing sources of energy will decrease since oil is a limited asset. Throughout the years, the expense of power has ascended to exceptional levels due the restricted supply of oil and monetary and political elements. Along these lines, renewable energy is a more appealing other option to electricity generation, as it will likewise give a cleaner environment to future eras.

Renewable energy can be made by numerous strategies; for example, solar energy, wind energy, hydro energy, nuclear energy, and many more. In today's world, electricity would cost a lot of energy and resources and cause natural resources increasingly disturbed [1]. To reduce energy consumption, recycling energy would be another alternative reaching green environment technology of renewable energy. Recently, 50% of total energy demand are used to support air conditioning aims to achieve human comfort [2]. Therefore, heat recovery shows a promising way in renewable energy usage. Waste heat from the condenser of split unit air conditioning system were used to generate electricity by using thermoelectric generator (TEG). However, few research was done to looks on capability of domestic split unit air conditioning system in generating electricity [3]–[6]. This study aim to develop a device that could collect waste heat from split unit condenser that could generate electricity, hence monitor the current generated respectively.

LITERATURE REVIEW

A. Air conditioning system

Generally, the purpose of air-conditioning system is to maintain the indoor air quality and to provide thermal comfort inside the conditioned space. The application of air-conditioning system in daily life makes residences or occupants to be more comfortable especially in a warm climate country like in Malaysia. The usage of split unit system are very popular for small scale application especially household [7]. Commonly, air-conditioning system can be divided into two categories, which are unitary refrigerant system, and the other one is centralized system. Both of these systems are known as conventional air-conditioning system, which depending on the vapor compression cycle [8]. However, the waste generated from condenser were not fully utilize. A split air conditioner consists of two main parts: the outdoor unit and the indoor unit. The outdoor unit is installed on or near the wall outside of the room or space that you wish to cool. The unit houses the compressor, condenser coil and the expansion coil or capillary tubing. The sleek-looking indoor unit contains the cooling coil, a long blower and an air filter. In this experiment, the heat from discharge pipe of compressor will be use to generate electricity [9].

B. Thermoelectric generator

Thermo-electric generators (TEG) are all strong state gadgets that change over warmth into power. These devices convert thermal energy into electricity without requiring any moving components [10]. The schematic of one thermoelectric generator are presented in Figure 1. The simplest thermoelectric generator consist of thermocouple of N type and P type elements connected electrically in series and thermally in parallel. When one side of TEG is hot, and other side a cooled, a Seeback effect are created [11], hence voltage are created [12]. The study of Seeback effect to the Heating Ventilation Air Conditioning (HVAC) equipment have shown several interest [13]–[15]. The heat recovery process mainly by the exhaust air and condenser hot air [16]. Therefore, this study present TEG peltier device to generate electricity from split unit air conditioning system [17].

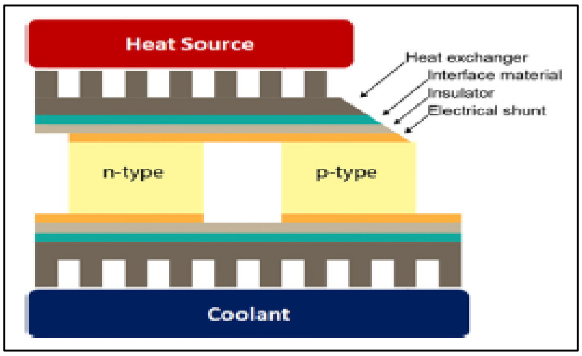

Figure 1: Schematic of thermoelectric generators working principle [12, 18]

METHODOLOGY

An air conditioning (split unit system) 1.5 Horsepower (HP), with cooling capacity 15 000 btu/hr (non-inverter) are selected to be used in this project. A device (peltier module) was developed to be attach at outdoor unit as shown in Figure 2 to make sure heat generated can be harvest and turn to electricity. This project was conducted in one of laboratory in Melaka, Malaysia where ambient temperature were set between 26- 28 °C and relative humidity 70%. The type of refrigerant use in the cycle is R22.

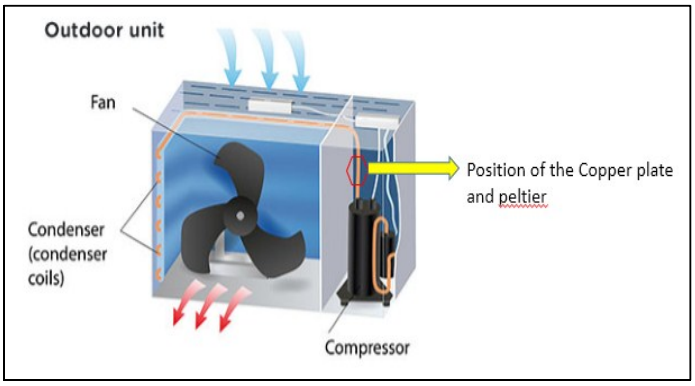

Figure 2: Outdoor unit and position of copper plate attach

A. Peltier module development

The peltier module were install at discharge pipe of the compressor. The size of the copper plate are 120mm x 60mm and 2mm thickness. Copper was used to trap the heat as copper shows 401 W/mK of thermal conductivity value. Six TEG peltier module were arranged and labelled accordingly as shown in Figure 3 [19]. The peltier module then were front and back sandwiches by copper plate, before being attach to the aluminium heat sink which shown in Figure 4. One copper plate were brazed and attached to the discharge pipe, meanwhile another copper plate were attach to the heat sink [20]. Then TEGs were installed between the heat sinks by using thermal grease, which as to increases the thermal conductivity by balancing irregular surface of the heat sinks. A water tank used to collect condensation water from the evaporator before being flown through the heat sink [21].

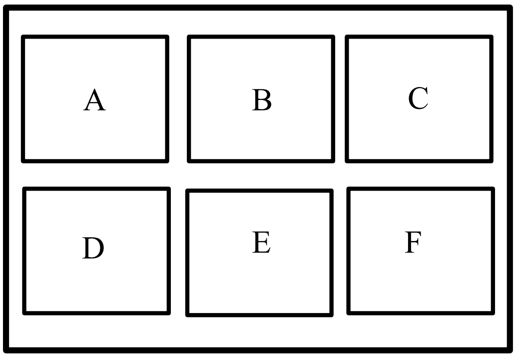

Figure 3: Six TEG peltier arrangement

RESULT AND DISCUSSION

Several data were reported in this experiment including peltier development and temperature data monitoring. Figure 5 represent the TEG peltier device that have been developed. Meanwhile, Figure 6 present overall picture to shows the experiment works. Condensation water from the evaporator were flow through the heat sink [22]. Based on split unit set situation, water temperature shows 5 °C, 7 °C and 9 °C respectively flow through the heat sink [23]–[25]

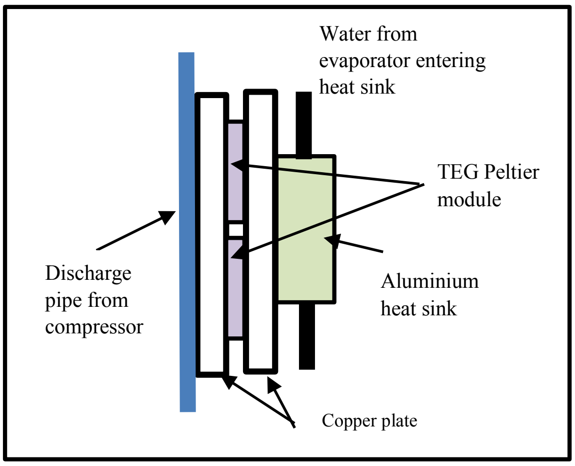

Figure 4: Side view of TEG peltier attach to the copper plate and heat sink

The current generated from split unit air conditioner were monitor from the first minutes until 30 minutes of operation. Type K thermocouple and Fluke data logger were used to collect temperature values in this experiment. The difference temperature between hot plat and cold plate also been monitored. The air conditioner was sets in three different situations. Table 1 illustrates the three differences situation for the split unit used in this project. The difference temperature between hot plat and cold plate also been monitored. The air conditioner was sets in three different situations. Table 1 illustrates the three differences situation for the split unit used in this project.

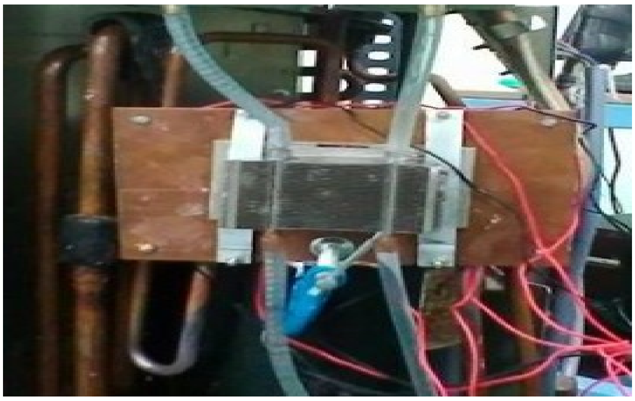

Figure 5: TEG Peltier device development

Table 1: Coil temperature refer to 3 case experiment

Case	Evaporator coil temperature	Condenser coil temperature	ΔT
1	3 °C	80 °C	77 °C
2	6 °C	76 °C	70 °C
3	9 °C	71 °C	62 °C

Data were collected for 5 times. Voltage output were then arranged in parallel series and by using Joule Thief method to maximize the voltage output from the peltier device. A piping system based on condensate water was also developed, which contain water from evaporator. The different temperature of the device module will create and generate electricity [24].

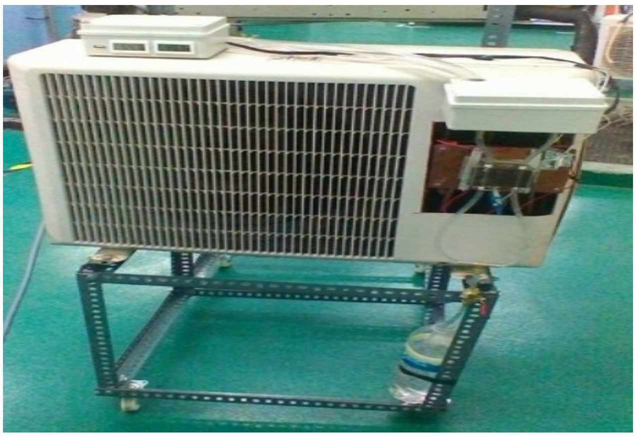

Figure 6: Overall experiment layout

Based on 3 cases, depending on evaporator and condenser temperature, several data were taken. From Figure 7, the temperature of hot copper plate is significantly correlated with the evaporator and condenser temperature [26]. Case 1 shows evaporator temperature at the lowest temperature, and significantly increase the condenser temperature and increase **ΔT.** Therefore, data taken to monitor electricity current generated will be benchmark case 1 where evaporator temperature at 3°C, and condenser temperature at 80 °C.

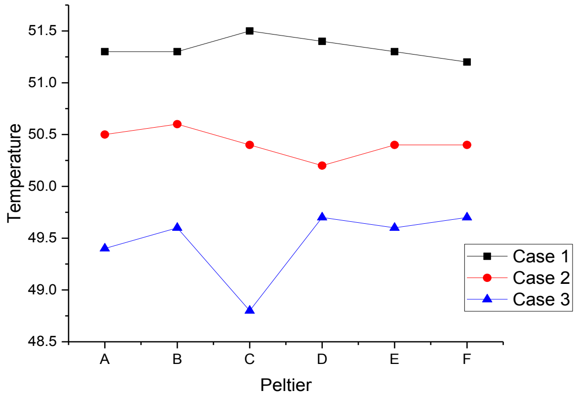

Figure 7: Hot copper plate temperature against set evaporator coil temperature

Table 2: Peltier and temperature data

Peltier	T (^{0}C) Plate Hot	T (^{0}C) Plate Cold	ΔT (^{0}C)
A	51.3	41.5	9.8
B	51.3	41.3	10
C	51.5	41.2	10.3
D	51.4	41.2	10.2
E	51.3	41.4	9.9
F	51.2	41.5	9.7

Table 2 illustrates the different temperature data for each pelter. There are none obvious different temperature on all peltier. Averagely, the ΔT for all peltier are ranging from 9.7 °C to 10.3 °C. Temperature for both hot and cold plate shows uniform heat transfer for all plate [18]. Therefore, with the arrangement of six TEG peltier, the voltage output for each peltier are no drastically different. Table 2 represent temperature data varies with time operated for all 6 six peltier. From Figure 8, voltage output for peltier B significantly shows the highest voltage output compare to other peltier. The trend for all peltier shows that the peltier device start to generate voltage at the third minutes of split unit operation. However, the current start to decrease for all the data at 6 minutes of operation, and start rapidly increase back at the 12 minutes of operation. This phenomena are slightly depended on the compressor where start to fully compress at the 12 minutes of operation [24].

Table 3: Voltage generated for each peltier against time

Time (m)	A	B	C	D	E	F
3	0.23	0.24	0.22	0.20	0.17	0.22
6	0.21	0.29	0.20	0.22	0.17	0.21
9	0.20	0.27	0.19	0.20	0.16	0.19
12	0.18	0.24	0.18	0.18	0.14	0.18
15	0.20	0.24	0.20	0.20	0.18	0.22
18	0.22	0.31	0.22	0.24	0.21	0.24
21	0.25	0.33	0.25	0.25	0.22	0.26
24	0.27	0.35	0.27	0.27	0.24	0.28
27	0.26	0.34	0.25	0.25	0.23	0.26
30	0.27	0.33	0.26	0.26	0.22	0.27

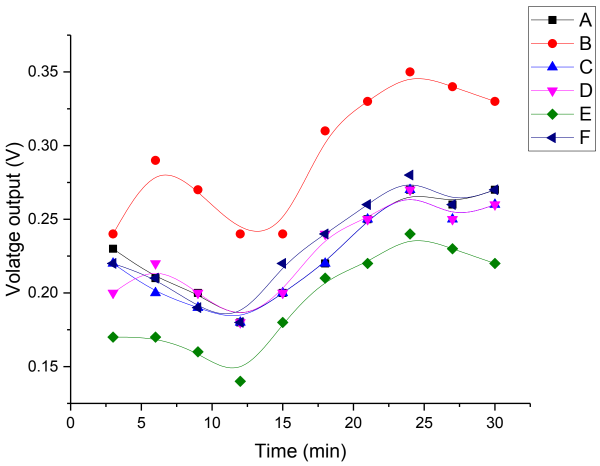

Figure 8: Voltage output for each peltier

The six TEGs were connected electrically in series into an array whose electrical characterization was performed with TEG A, B, C, D, E, and F (0.27 V, 0.33 V, 0.26 V, D 0.26 V, 0.22 V and 0.27 V) respectively. The peltier B shows the highest value of voltage output as it is on top of the discharge pipe where it brazed to the copper plate. This value are represent the data where the peltier device and split unit air conditioning already operated at 30 minutes, and shows maximum number of voltage output. The total maximum voltage can be extracted from these peltier device is 1.61 V with the sum of all voltage from each peltier.

CONCLUSION

The development of this peltier device shows promising data to generate voltage from the heat recovery method. The difference temperature between hot plate and cold plate where around 9 – 10 °C relatively generated 1.61V. The peltier device that have been develop using thermoelectric generator (TEG) shows basic concept of thermoelectric power, and the relevant application to the waste heat energy recovery. Thermo-electric frameworks can be effectively intended to work with little warmth sources and little temperature contrasts. These can indicates that TEG technologies are suitable devices for waste heat recovery for split unit air conditioning system.

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