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EXPERIMENTAL INVESTIGATION ON THERMOELECTRIC GENERATOR SYSTEM FOR PERFORMANCE ENHANCEMENT

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ABSTRACT

Experimental Investigation on thermoelectric generator system consisting couple of Thermoelectric Generator modules using two different energy sources, one is solar water heater and the other is gas cartridge heating torch is carried out. Solar energy is used to heat the water through solar water heater to supply heat at the hot side of Thermo Electric Generator (TEG) creating the temperature difference for power generation. This concept is suitable for hot atmosphere like summer season in India, solar radiation is high. The main objective of investigation is to study the performance of TEG for power generation using different energy source i.e. the low temperature source which is considered as the solar water heater and high temperature source as gas cartridge heating torch. The maximum temperature of the hot side of TEG modules that is attained from solar water heater and gas cartridge heating torch are 90^0 C and 300^0 C respectively. It is observed that hot side temperature through solar water heater is limited to 120^0 C. Therefore, operating temperature range for two energy sources is different. In order to check suitability of TEG module for power generation at low and high temperatures two TEG modules are utilized. TEG Module 1268- 4.3 and TEG Module 4199-5.3 are connected in series as well as parallel both combinations are investigated. Conversion efficiency of TEG is obtained maximum at higher temperature difference i.e. during gas cartridge heating torch.

INTRODUCTION

Thermoelectric (TE) devices can be used for power generation and refrigeration. TE devices designed to generate power through the Seebeck effect are called TE generators (TEGs). TE devices have numerous advantages such as no moving parts to cause vibration or noise, high reliability and environmental friendly (Simons *et al*., 2005; Wang *et al*., 2012). Some studies developed the concept of thermoelectric self-cooling (Martinez *et al*., 2011) and the combination of TECs and solar cells for green building (Cheng *et al*., 2011). As far as TEG is concerned, its conversion is a simple and reliable solid-state technology (Thacher *et al*., 2007). Seeing that TEGs can be employed for power generation by recovering waste heat as a heat source, much research has been done. For example, some attention has been paid to the recovery of waste heat from automobiles. Seeing that TEGs can be employed for power generation by recovering waste heat as a heat source, much research has been done. For example, some attention has been paid to the recovery of waste heat from automobiles.

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Thacher *et al*. (2007) tested the performance of 16 HZ-20 generators which were connected in series and placed in automobile exhaust. They found that output and their results suggested that the improvement on thermal resistances at both sides of heat exchangers was important. Gou *et al*. (2010) established a theoretical model and constructed a low temperature waste heat recovery system with 10 TEMs in series. They found that increasing waste heat temperature and adding TEMs in series could enhance the performance of the setup. Hsu *et al*. (2011) simulated and tested the performance of a waste heat recovery system which comprised 24 TEGs in series. Zhu *et al*. (2011) studied the influence of heat source power, hot-side temperature, load resistance and Peltier effect on the performance of TEG by a series of experiments. They also discussed the performance of TEGs in parallel. It was reported that a loop current was produced from the non-uniformity among parallel TEGs so that the loading capability of the overall power system was decreased. Liang *et al*. (2011) further proposed the analytical model of parallel TEG and they found that the parallel characteristics of two parallel TEGs were different from common DC power due to the non-uniformity between the TEGs.

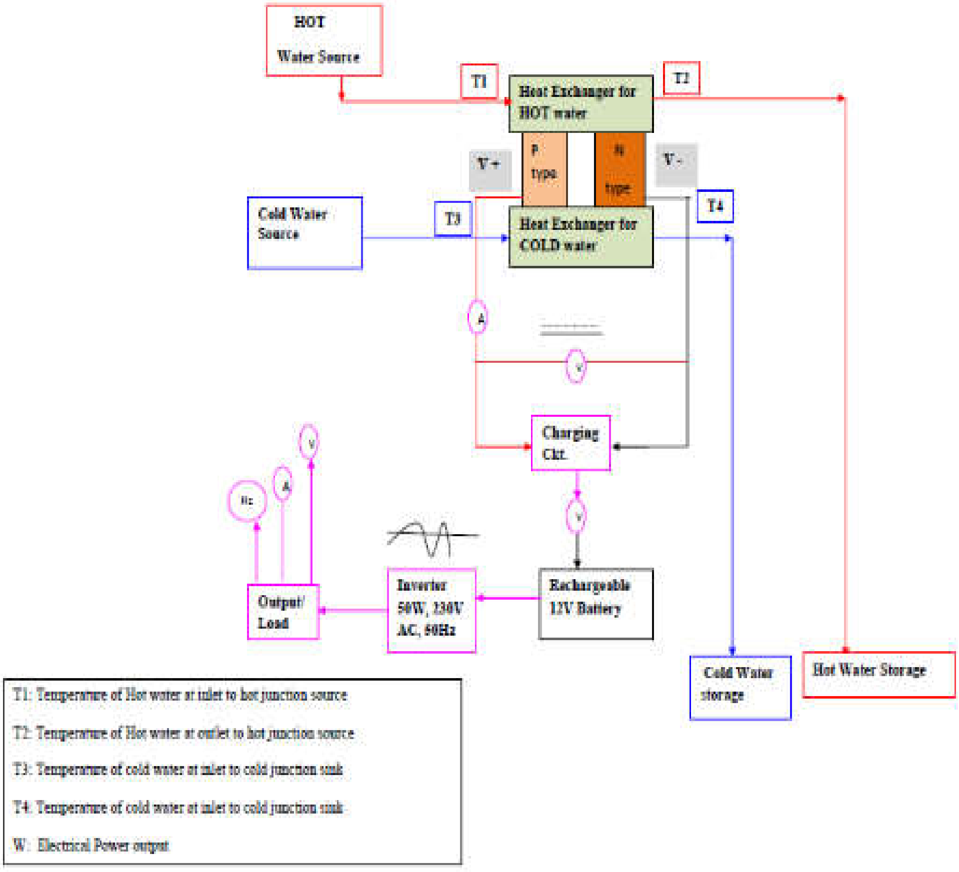


Figure 1. (a) Line diagram for Investigation setup [15]

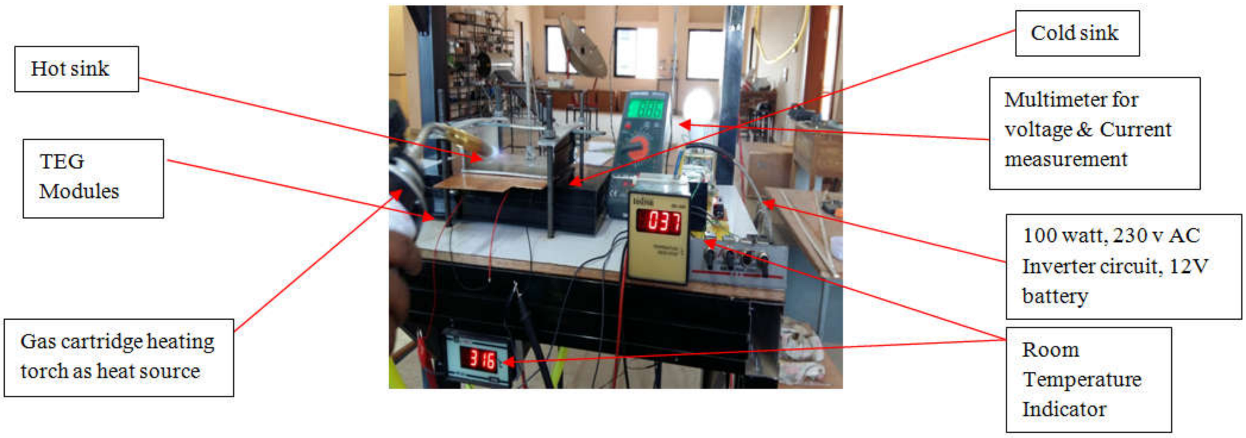


Figure 2. Picture of TEG experimental setup with Gas cartridge heating torch as heat source

Application of TEG with Solar Water Heater	Hot water Tap Temp (°C)	Cold water Tap Temp (°C)	Hot side Temp (°C)	Cold side Temp (°C)	Voltage (V)	Current (A)	Power Output (W)
TEG Module 1268-4.3	94	17	80	30	2.76	0.625	1.725
TEG Module 4199-5.3	94	15	80	30	3.26	0.750	2.445
Connected in Series	90	15	80	30	5.3	0.390	2.067
Connected in parallel	90	14	80	30	2.11	1.2	2.532

TEG modules with gas cartridge Torch as heat source	Cold water Tap Temp (°C)	Hot side Temp (°C)	Cold side Temp (°C)	Voltage (V)	Current (A)	Power Output (W)
TEG Module 1268-4.3	15	300	30	5.25	0.970	5.0925
TEG Module 4199-5.3	15	300	30	6.8	0.920	6.256
Connected in Series	15	300	30	12	0.690	8.28
Connected in parallel	15	300	30	4.93	1.100	5.423

Despite the parallel connection of TEGs conducted (Zhu *et al*., 2011; Liang *et al*., 2011), the serial connection was absent. In the study of Gou *et al*. (2010), the effect of TEMs in series on power generation has been analyzed theoretically; but experiments were absent. For these reasons, the present study is intended to experimentally explore the performances of TEMs under various combinations. Unlike fluids or heat exchangers were utilized in certain studies, the present study adopts heaters to provide thermal energy into the hot side of the modules. Other parameters such as the heating temperature and the flow pattern and flow rate of cold fluid will also be discussed.

Experimental Method

Experimental Apparatus and procedure

A schematic of investigation setup and picture of TEG experimental system is shown in Fig. 1 and 2. The system was developed by a hot and cold sink, TEG modules i.e. TEG Module 1268-4.3 and TEG Module 4199-5.3, Solar water heater and Gas cartridge heating torch as heat source, Micro multimeter for current and voltage measurement, 100 watt, 230 v AC Inverter circuit, 7 Amp/12 Volt rechargeable battery, charging controlled circuit.

METHODOLOGY

Following is the methodology adopted for project

- Study of thermoelectric generators performance for research gap finding through exhaustive literature review is done.
- Study of the important causes for thermoelectric generators low conversion efficiency is carried out.
- Study of field data available regarding the factors affecting thermoelectric generator performance is done.
- Study of the different factors such as source temperature, sink temperature on material properties such as figure of merit, Seeback coefficient, and electric resistivity affecting thermoelectric generator performance is done.
- Setup is purchased and experimentally possible enhancement of power output from a particular thermoelectric generator via market availability of thermoelectric generator & their technical specification study is carried out.
- Experimental work is carried out by: A) TEG experimental setup with Solar water heater as heat source has developed and tested in series and parallel connection. B) TEG experimental setup with Gas cartridge heating torch as heat source has developed and tested in series and parallel connection.

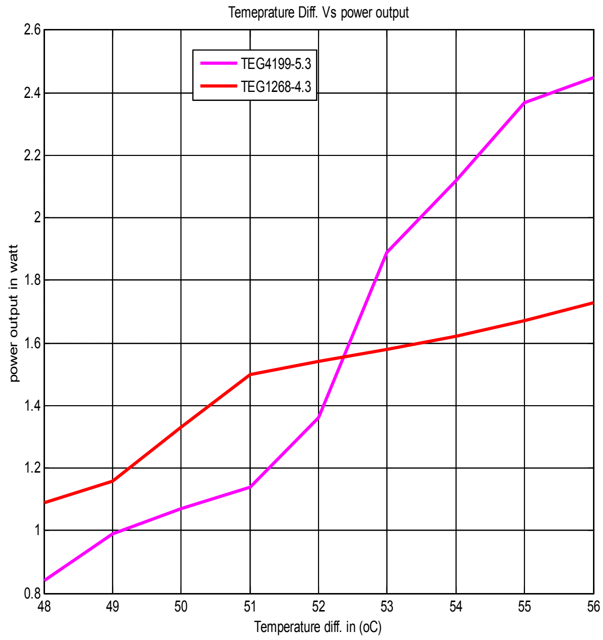
RESULTS AND DISCUSSION

Results (Observation Table)

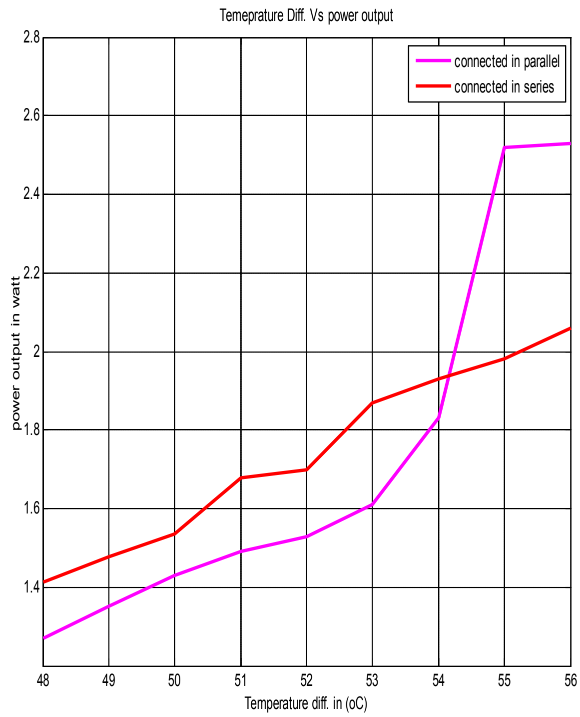
- TEG experimental setup with solar water heater as heat source
- TEG experimental setup with Gas cartridge heating torch as heat source

DISCUSSION

TEG experimental setup with Solar water heater as heat source is developed and tested, following points are observed Maximum hot side temperature from solar water heater is obtained at 80 °C and cold side temp is at 30 °C power developed by two different TEG modules (TEG Module 1268-4.3 and TEG Module 4199-5.3) are 1.725 W and 2.445 W respectively as shown in graph.1 2. At the same working condition using two TEG modules in series and parallel arrangements, power output is obtained 2.067 W and 2.532 W respectively as shown in Graph 2



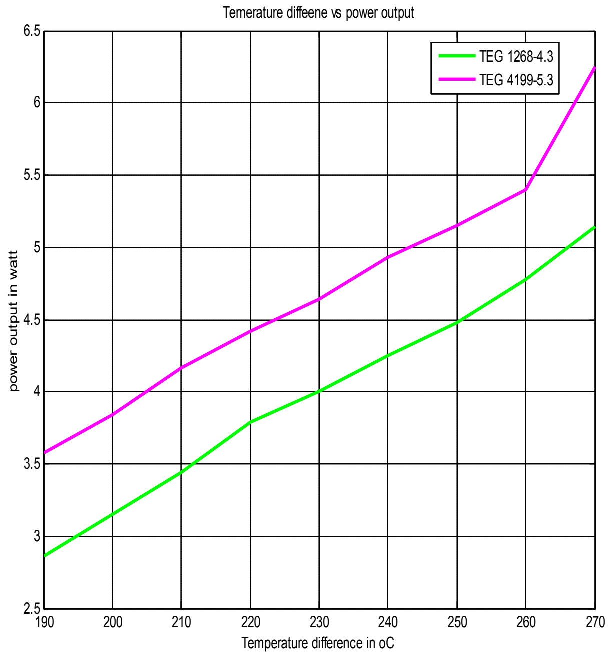
Graph 1. Temperature difference vs Power output (Solar heating water as heating source)



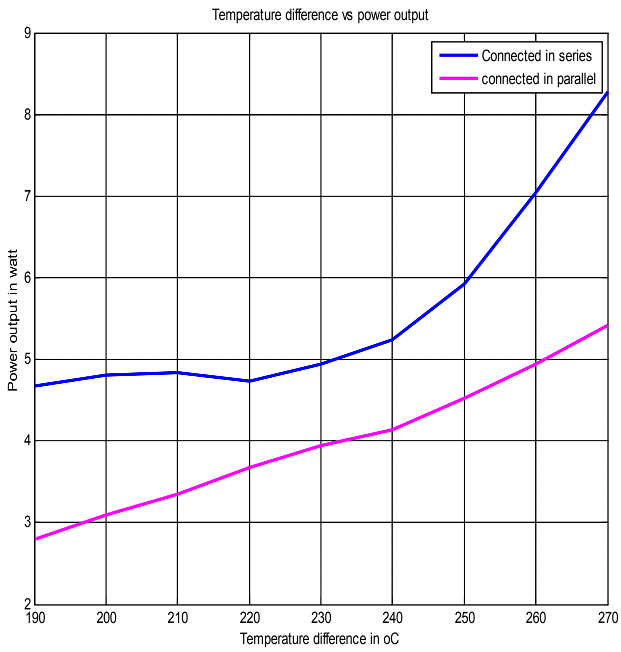
Graph 2. Temperature difference vs Power output when TEG connected in parallel and series (Solar heating water as heating source)

TEG experimental setup with Gas cartridge heating torch as heat source is developed and tested, following points are observed. Hot side temperature is maintained at 300 °C and cold side temperature at 30 °C i.e. temperature difference 270 ^{0}C and power output of both TEG modules (TEG Module

1268-4.3 and TEG Module 4199-5.3) is measured 5.0925 W and 6.256 W resply. as shown in graph 3.



Graph 3. Temperature difference vs. power output (Gas cartridge torch as heating source)



Graph 4. Temperature difference vs. Power output when TEG connected in parallel and series (Gas Cartridge heating torch as heating source)

At the same working conditions using two TEG modules in series and parallel arrangements, power output is obtained 8.28 W and 5.423 W respectively as shown in Graph 4.

Conclusion

As per the study of thermoelectric generators performance analysis, it is found that various factors such as figure of Merit, electrical conductivity, thermal Conductivity, Seeback coefficient etc. are affecting on performance of Thermoelectric generator.

So it is clear that to improve the performance of a thermoelectric generator the electrical conductivity should be increased and thermal conductivity should be reduced. As per the study it is found that important causes for low conversion efficiency of the thermoelectric generator depends upon the figure of merit for materials, it is key consideration for comparing the efficiency of thermoelectric material greater the value of figure of merit more will be the conversion efficiency of a thermoelectric material and vice versa. As per the study it is clear that effective thermoelectric materials should have a low thermal conductivity but a high electrical conductivity. A lot of research in thermoelectric materials is focused on increasing the See back coefficient and reducing the thermal conductivity, especially by manipulating nanostructure of thermoelectric materials. It is found that experimental data generated shows potential increased in module conversion efficiency thereby increased in power output capacity.

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