Performance Analysis of Thermo Electric Generator using MATLAB

Sreekala P, **A Ramkumar** , **K.Rajesh**,

Abstract: — ***In this paper discussed with the mathematical model of thermo electric generator. Designed each blocks based on mathematical equation and by using the equations they are connected and verified the output. The peak energy is achieved when the internal resistance of the TEG is equal to the resistance of the load. In order to increase the existing transport,voltage carrying and power rating the thermo electric generators are connected in series, parallel or series -parallel connections. The mathematical model is simulated in matlab and the results are verified.***

Keywords : ***Thermo Electric Generator, Thermal Conductivity, Voltage , Current***

I. INTRODUCTION

The thermo electric is solid state energy converting device working with Seebeck effect .Power generation using thermo electric method is clean energy.. Electricity is produced by the keeping thermo electric generator in flat plate or curved surface. Thermoelectric module converts the difference in temperature between the top and bottom surface of the module to electric energy directly. Thermo electric module is classified into two thermo electric generators and thermo electric coolers .Thermo electric coolers works on the principle of Peltier effect. In this system there are no mechanical or moving parts. Thermo electric module can provide noiseless, reliable and stable operation. Thermo electric coolers are used in cooling and refrigeration that is coolers in optoelectronic and portable electric food coolers. Thermo electric coolers are also used in temperature control application. Thermo electric generators are used to produce energy from waste heat. The thermo electric generator is very important in power generation from wireless communication and remote self-powered waste heat systems.

TEGs mathematical models are developed to simulate and analyze its performance TEG model using the Matlab / Simulink .

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II. THERMOELECTRIC GENERTOR

Thermoelectric generators are converting thermal energy into electric energy. The electrical voltage is generated between two ends of two different metals they welded together maintaining at different temperature.

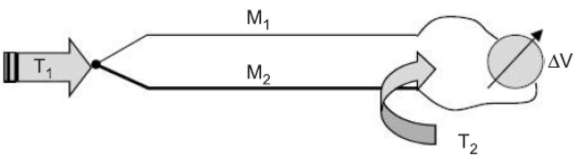

Fig.1. Thermo Electric Generator

Voltage developed:

$$\Delta V = \alpha_s \Delta T \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: α_s - Seebeck coefficient

ΔV - Voltage difference in Volts

ΔT - Absolute temperature difference in Kelvin

Bulk effect of Seebeck coefficient can be determined by the following effects: Temperature difference of the TEG generates due to the difference in Fermi level. Bandgap distance also changes with temperature. With respect to function of temperature, the gradient of charge carriers changes the n and p type. In general, the diffusion coefficient of TEG is varied based on the function of temperature. By thermo diffusion, charge carriers switch from the warm side to the cold side. The charging carriers produce electric field. The effect of Seebeck is primarily used in thermocouples for temperatures ranging from -200 to 1600 ° C.

Thermal conductivity is used to explain the thermal conduction phenomenon:

$$Q_c = -\Delta T K_{th} \ldots\ldots\ldots\ldots (2)$$

Let K_{th} is the module thermal conductivity

and $\Delta T = T_H - T_C$. The electric current flows through the module cause additional resistive heat loss. The total heat loss in thermo electric module is:

$$Q_R = I^2 R \ldots\ldots\ldots\ldots (3)$$

The output voltage of TEM is:

$$V = \Delta V + IR \ldots\ldots\ldots\ldots (4)$$

A good thermo electric generator combines a High, low electrical resistance Seebeck coefficient R..The FOM (Figure of merit) is:

$$Z = \frac{\alpha_s^2}{RK_{th}} \quad \ldots\ldots (5)$$

III. PARAMETER CALCULATION

For calculating the parameter of thermo electric generator first considers cold and hot side temperatures. W_L is the load power. The load resistance R_L is compared to the thermoelectric module's internal resistance R and the load voltage V_L .By using the data sheet we can calculate the electrical parameters directly. The internal resistance of a TEG can be expressed as R and the αs (Seebeck coefficient).:

$$R = R_L = \frac{V_L^2}{W_L} \quad \ldots\ldots (6)$$

$$\alpha_s = \frac{2V_m}{\Delta T} \quad \ldots\ldots (7)$$

The efficiency of thermo electric generator is function of load. The RL is known as R_L = mR with m being the R_L and R ratio of the thermoelectric module. The current through the TEG can be expressed as:

$$I = \frac{\alpha_s \Delta T}{[(1+m)R]} \quad \ldots\ldots (8)$$

A TEG's thermal efficiency is defined as the ratio of the electrical output power to the heat input power, which can be expressed as:

$$\eta_{th} = \frac{I^2 R_L}{Q_H} \quad \ldots\ldots (9)$$

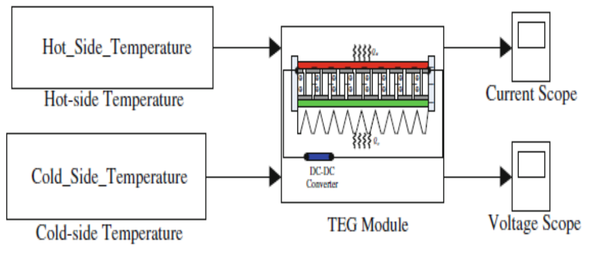

Fig.2. Model of Thermo Electric Generator

The TEG can be connected in three different methods they are described below.

A. *Series Configurations*

In series configuration the TEGs are connected in series. This configuration will increase the output voltage.

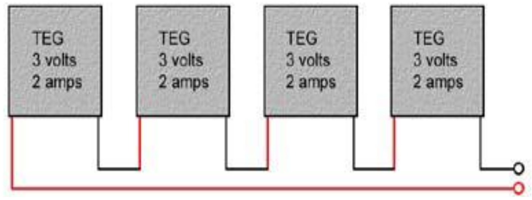

Fig.3. Series Configuration of Thermo Electric Generator

B. *Parallel Configuration*

In parallel configuration the TEGs are connected in parallel. This configuration increases the output current.

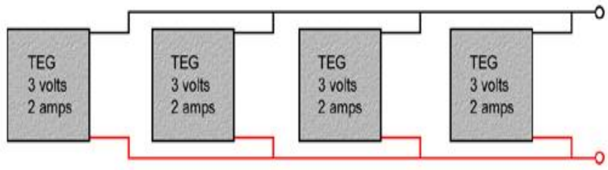

Fig.4. Parallel Configuration of Thermo Electric Generator

C. *Series-Parallel Configuration*

This configuration is the combination of parallel and series configuration of TEG. Those configuration increases the current and voltage capacity.

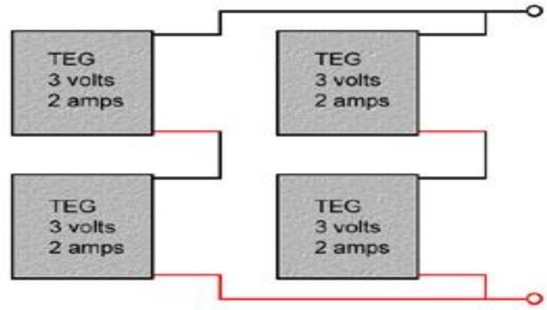

Fig.5. Series-Parallel Configuration of Thermo Electric Generator

The comparison of three configurations can be represented by using graph. From the graph series parallel configuration give better output than other two. For this reason, the configurations are selected.

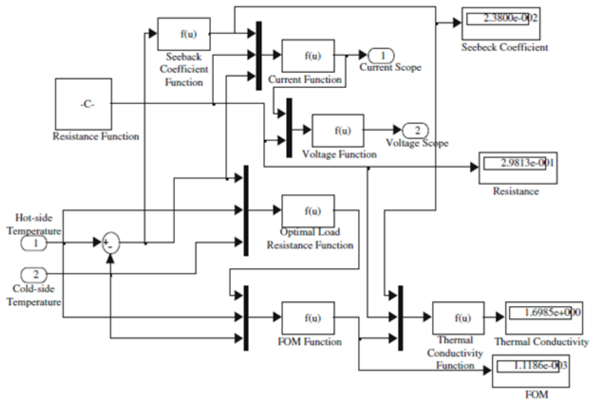

Fig. 6. Mathematical Model of TEG Subsystem

IV. SIMULATION RESULT

Take HZ-20 thermo-electric unit, pick TH=2300C, TC=300C, Wm=19W, Vm=2.38V and η_{max}=4.5 % from their data sheet. = 0:0238 V / K; R=0:2981; Kth 1:6985 W / K and Z=0:0011 K-1.. The V-I characteristics and Power- Current characteristics are plotted. The thermo electric generator produces maximum power when R_L is equal to R. This result summarizes that the maximum power is approximately 19 W at I = 7,9832 A and V = 2,3800 V, and the average thermal efficiency is 4.5 percent when reaching approximately 7.2 A. The data sheet values shown below are the energy Vs Temperature, Voltage Vs Temperature & Efficiency Vs Temperature.

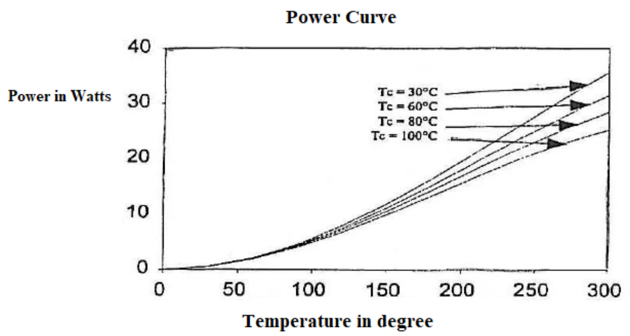

Fig. 7. Power Vs Temperature Curve

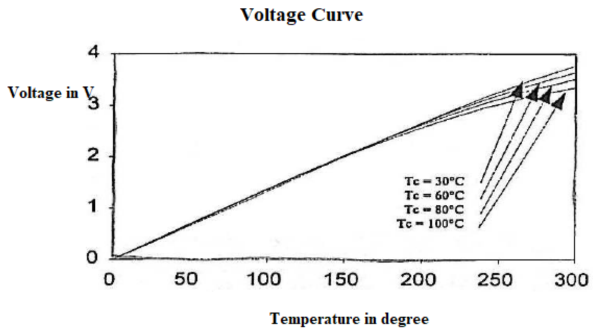

Fig. 8. Voltage V_s Temperature Curve

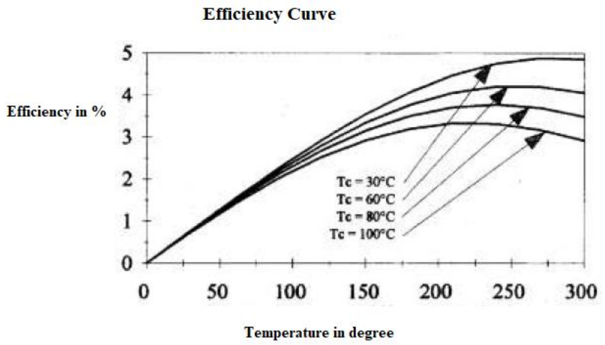

Fig. 9. Efficiency Vs Temperature Curve

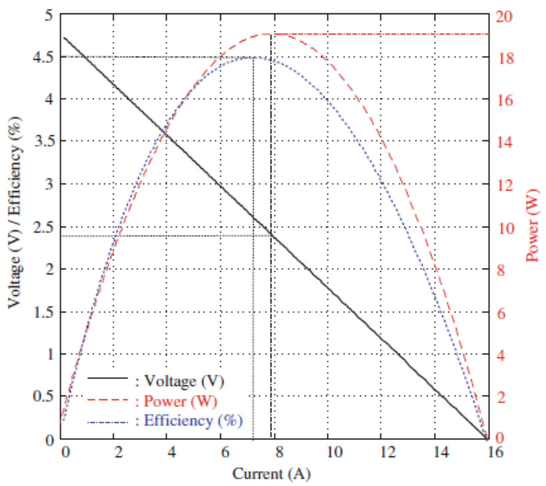

Fig 10. V-I and Power_I characteristics

V. CONCLUSION

Modelled the model of thermo electric generator. The maximum power is obtained when load resistance is equal to internal resistance. The results are validated. For getting more output power, voltage and current different connection combinations can be used. The hot surface properties of the module are 230 ° C (450 ° F) from the current-voltage curve and the cold surface of the module is 30 ° C (90 ° F).The value obtained from the graph is validated with simulation results.

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