

Technical Brief Basics on TEG Power Generation

13.0 Power Generation

13.1 Bismuth Telluride-based thermoelectric power modules are designed primarily for cooling or combined cooling and heating applications where electrical power creates a temperature difference across the module. By using specially designed TEG modules that use higher temperature bonding materials and techniques specifically designed to aid the modules to withstand extreme temperatures modules "in reverse," Can be used as Seebeck effect modules whereby a temperature differential is applied across the faces of the module, it is possible to generate electrical power. Useful power often may be obtained where a source of heat is available. The higher the heat and the greater the DT the more power can be generated.

13.2 A thermoelectric TEG power module used for power generation has certain similarities to a conventional thermocouple. Let us look at a single thermoelectric couple with an applied temperature difference as shown in Figure (13.1)

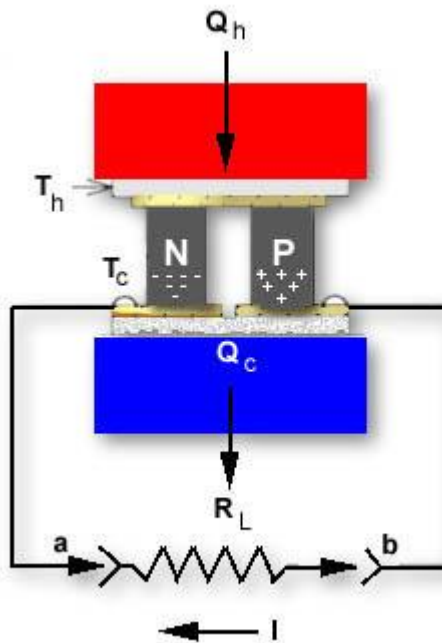


Figure (13-1)
Single Thermoelectric Couple where $T_h > T_c$

With no load (R_L not connected), the open circuit voltage as measured between points a and b is:

$$V = S \times \Delta T$$

where:



V is the output voltage from the couple (generator) in volts

S is the average Seebeck coefficient in volts/°K

DT is the temperature difference across the couple in °K where $DT = T_h - T_c$ at Junctions

When a load is connected to the thermoelectric couple the output voltage (V) drops as a result of internal generator resistance. The current through the load is:

$$I = \frac{S \times DT}{R_C + R_L}$$

where :

I is the generator output current in amperes

R_c is the average internal resistance of the thermoelectric couple in ohms

R_L is the load resistance in ohms

The total heat input to the couple (Q_h) is:

$$Q_h = (S \times T_h \times I) - (0.5 \times I^2 \times R_c) + (K_c \times DT)$$

where:

Q_h is the heat input in watts

K_c is the thermal conductance of the couple in watts/°K

T_h is the hot side of the couple in °K

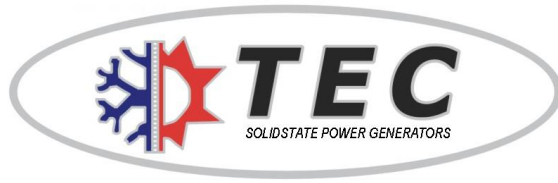
The efficiency of the generator (E_g) is:

$$E_g = \frac{V \times I}{Q_h}$$

We have thus far discussed an individual thermoelectric couple, but since a complete module consists of a number of couples, it is necessary to rewrite our equation for an actual module, as follows:

$$V_o = S_M \times DT = I \times (R_M + R_L)$$

where:



V_o is the generator's output in volts

SM is the module's average Seebeck coefficient in volts/°K

RM is the module's average resistance in ohms

It must be remembered that module Seebeck coefficient, resistance and thermal conductance properties are temperature dependent and their values must be calculated as such. In either case, the values of SM , RM , and KM must be selected at the average module temperature T_{avg} where:

$$T_{avg} = \frac{T_h + T_c}{2}$$

The power output (P_o) from the module in watts is:

$$P_o = R_L \times$$

It is possible, but unlikely, that the precise conditions will exist within a given generator application whereby one module will provide the exact output power desired. As a result, most thermoelectric generators contain a number of individual modules which may be electrically connected in either series, parallel, or series/parallel arrangement. A typical generator configuration is illustrated in Figure (13.2). This generator has a NT total number of modules with NS number of modules connected in series and NP number of modules connected in parallel. The total number of modules in the system is:

$$NT = NS \times NP$$

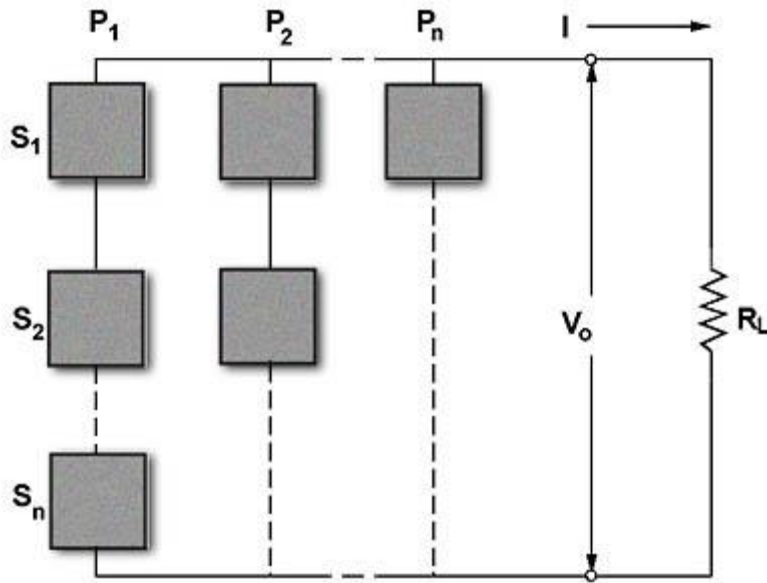


Figure (13-2)
Typical Thermoelectric Generator with a Series-Parallel Arrangement of Modules

The current (I) in amperes passing through the load resistance RL is:

$$I = \frac{NS \times S_M \times DT}{\frac{NS \times R_M}{NP} + R_L}$$

The output voltage (Vo) from the generator in volts is:

The Output Power (Po) from the generator in watts is:

$$P_o = V_o \times I = \frac{NT \times (S_M \times DT)^2}{4 \times R_M}$$

The total heat input (Qh) to the generator in watts is:



The efficiency (E_g) of the generator is:

$$E_g = \frac{P_o}{Q_h} \times 100\%$$

Maximum efficiency occurs when the internal resistance of the generator (R_{GEN}) equals the load resistance (R_L). The generator resistance is:

$$R_{GEN} = \frac{NS \times R_M}{NP}$$