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THERMO-ELECTRIC POWER GENERATION USING SOLAR AS AN ALTERNATIVE GREEN TECHNOLOGY

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ABSTRACT

In recent years, an increasing concern of environmental issues of emissions, in particular global warming and the limitations of energy resources has resulted in extensive research into novel technologies of generating electrical power. Thermoelectric power generators have emerged as a promising alternative green technology due to their distinct advantages. Their typical efficiencies are around 5-8%. Older Seebeck-based devices used bimetallic junctions and were bulky while more recent devices use semiconductor p-n junctions made from bismuth telluride (Bi2Te3), lead telluride (PbTe), calcium manganese oxide, or combinations thereof, depending on temperature. These are solid state devices and unlike dynamos have no moving parts, with the occasional exception of a fan or pump. In this paper the recent patents of solar thermo-electric power generation with their important and relevant applications to solar energy as a backup protection &storage of power will be reviewed and discussed. It is proposed to develop thermo electric power generator which use solar energy as a alternative green source to develop power.

INTRODUCTION

A thermoelectric power generator is a solid state device that provides direct energy conversion from thermal energy (heat) due to a temperature gradient into electrical energy based on “Seebeck effect”. The thermoelectric power cycle, with charge carriers (electrons) serving as the working fluid, follows the fundamental laws of thermodynamics and intimately resembles the power cycle of a conventional heat engine. Thermoelectric power generators offer several distinct advantages over other technologies.

- they are extremely reliable (typically exceed 100,000 hours of steady-state operation) and silent in operation since they have no mechanical moving parts and require considerably less maintenance;
- they are simple, compact and safe;
- they have very small size and virtually weightless;
- they are capable of operating at elevated temperatures;
- they are suited for small-scale and remote applications typical of rural power supply, where there is limited or no electricity;
- they are environmentally friendly;
- they are not position-dependent; and
- They are flexible power sources.

The major drawback of thermoelectric power generator is their relatively low conversion efficiency (typically ~5%). This has been a major cause in restricting their use in electrical power generation to specialized fields with extensive applications where reliability is a major consideration and cost is not. Applications over the past decade included industrial instruments, military, medical and aerospace, and applications for portable or remote power generation. However, in recent years, an increasing concern of environmental issues of emissions, in particular global warming has resulted in extensive research into nonconventional technologies of generating electrical power and thermoelectric power generation has emerged as a promising alternative green technology.Vast quantities of solar heat are discharged into the earth's environment much of it at temperatures which are too low to recover using conventional electrical power generators. Thermoelectric power generation (also known as thermoelectricity) offers a promising technology in the direct conversion of thermal energy, such as solar into electrical power. Thermoelectric generators have also been used to provide small amounts electrical power to remote regions for example Northern Sweden, as an alternative to costly gasoline powered motor generators. In this solar heat powered thermoelectric technology, it is unnecessary to consider the cost of the thermal energy input, and consequently thermoelectric power generators' low conversion efficiency is not a critical drawback. In fact, more recently, they can be used in many cases, such as those used in cogeneration systems, to improve overall efficiencies of energy conversion systems by converting solar energy into electrical power.

In general, the cost of a thermoelectric power generator essentially consists of the device cost and operating cost. The operating cost is governed by the generator's conversion efficiency, while the device cost is determined by the cost of its construction to produce the desired electrical power output. Since the conversion efficiency of a module is comparatively low, thermoelectric generation using solar energy is an ideal application. In this case, the operating cost is negligible compared to the module cost because the energy input (fuel) cost is free. Therefore, an important objective in thermoelectric power generation using solar energy is to reduce the cost-per-watt of the devices. Moreover, cost-per-watt can be reduced by optimising the device geometry, improving the manufacture quality and simply by operating the device at a larger temperature difference. In addition, in designing high-performance thermoelectric power generators, the improvement of thermoelectric properties of materials and system optimization have attracted the attention of many research activities.Their performance and economic competiveness appear to depend on successful development of more advanced thermoelectric materials and thermoelectric power module designs.

In this paper, a background on the basic concepts of the thermoelectric power generation is presented through the applications implemented in the recent patents of thermoelectric power generation relevant to solar energy.

BASIC THEORY OF A THERMOELECTRIC POWER GENERATOR

The basic theory and operation of thermoelectric based systems have been developed for many years. Thermo-electric power generation is based on a phenomenon called "Seebeck effect" discovered by Thomas Seebeck in 1821. When a temperature difference is established between the hot and cold junctions of two dissimilar materials (metals or semiconductors) a voltage is generated, i.e., Seebeck voltage. In fact, this phenomenon is applied to thermocouples that are extensively used for temperature measurements.

Based on this Seebeck effect, thermoelectric devices can act as electrical power generators. A schematic diagram of a simple thermoelectric power generator operating based on Seebeck effect is shown in Fig. (**1**). As shown in Fig. (**1**), heat is transferred at a rate of $\dot{Q}_H$ from a high-temperature heat source maintained at T_H to the hot junction, and it is rejected at a rate of $\dot{Q}_L$ to a low-temperature sink maintained at T_L from the cold junction. Based on Seebeck effect, the heat supplied at the hot junction causes an electric current to flow in the circuit and electrical power is produced. Using the first-law of thermodynamics (energy conservation principle) the difference between $\dot{Q}_H$ and $\dot{Q}_L$ is the electrical power output $\dot{W}_e$. It should be noted that this power cycle intimately resembles the power cycle of a heat engine (Carnot engine), thus in this respect a thermoelectric power generator can be considered as a unique heat engine.

COMPOSITION AND SPECIFICATIONS OF A THERMO-ELECTRIC POWER GENERATOR

It is composed of two ceramic plates (substrates) that serve as a foundation, providing mechanical integrity, and electrical insulation for *n*-type (heavily doped to create excess electrons) and *p*-type (heavily doped to create excess holes) semiconductor thermo elements. In thermoelectric materials, electrons and holes operate as both charge carriers and energy carriers. There are very few modules without ceramic plates, which could eliminate the thermal resistance asso-ciated with the ceramic plates, but might lead to mechanical fragility of the module. The ceramic plates are commonly made from alumina (Al_2O_3), but when large lateral heat transfer is required, materials with higher thermal conductivity (e.g. beryllia and aluminum nitride) are desired. The semiconductor thermo elements (e.g. silicon - germanium SiGe, lead-telluride PbTe based alloys) that are sandwiched between the ceramic plates are connected thermally in parallel and electrically in series to form a thermoelectric device (module).

Modules	N	A (mm^2)	l (mm)	A/l (mm)
I-1-2	127	1.35×1.35	1.53	1.19
I-2-2	127	1.47×1.47	1.47	1.47
I-3-1	127	1.40×1.40	1.14	1.72
I-3-2	127	1.40×1.40	2.03	0.96
I-3-3	127	1.40×1.40	2.54	0.77
II-1-2	31	4.30×4.30	1.52	12.16
II-2-2	31	4.50×4.50	1.67	12.12
III-1-3	50	5.00×5.00	3.00	8.33

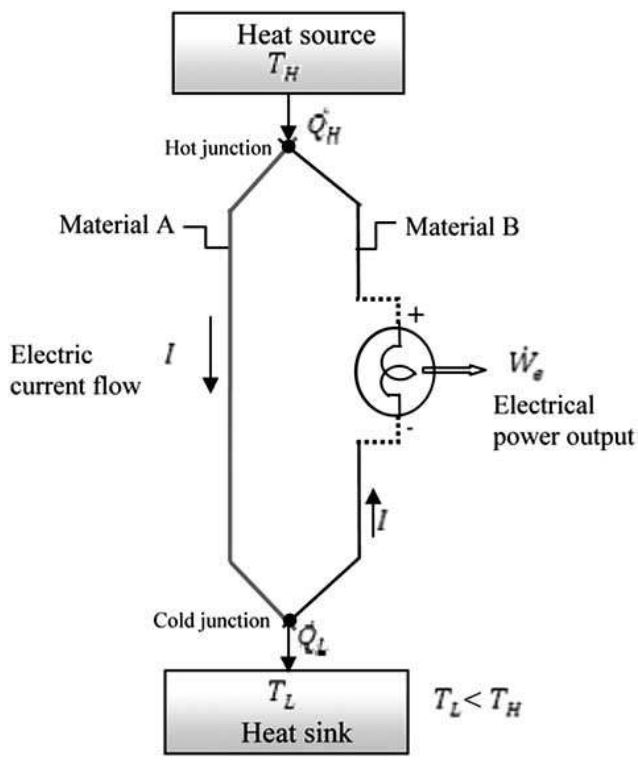


Fig:-1 Schematic diagram showing the basic concept of a simple thermoelectric power generator operating based on Seebeck effect.

More than one pair of semiconductors are normally assembled together to form a thermoelectric module and within the module a pair of thermo elements is called a thermocouple. The junctions connecting the thermo elements between the hot and cold plates are interconnected using highly conducting metal (e.g. copper) strips. The sizes of conventional thermoelectric devices vary from 3 mm^2 by 4 mm thick to 75 mm^2 by 5 mm thick. Most of thermoelectric modules are not larger than 50 mm in length due to Mechanical consideration. The height of single-stage thermoelectric modules ranges from 1 to 5 mm. The modules contain from 3 to 127 thermocouples. There are multistage thermoelectric devices designed to meet requirements for large temperature differentials. Multi-stage thermoelectric modules can be up to 20 mm in height, depending on the number of stages.

The power output for most of the commercially-available thermoelectric power generators ranges from microwatts to multi-kilowatts. For example, a standard thermo-electric device consists of 71 thermocouples with the size of 75 mm^2 can deliver electrical power of approximately 19 W. The maximum output power from a thermoelectric power generator typically varies depending on temperature difference between hot and cold plates and module specifications, such as module geometry (i.e. cross-sectional area and thermo element length), thermoelectric materials and contact properties. For a given temperature difference, there is a significant variation in maximum power output for different modules due to variation in thermo-electric materials, module geometry and contact properties. However, the maximum power output follows a clear trend and increases with a decrease in thermo element length for a given module cross-sectional area.

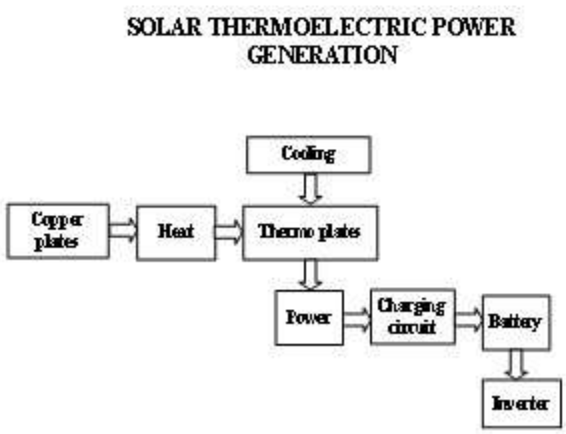
PERFROMANCE OF THERMO ELECTRIC POWER GENERATORS

The performance of thermoelectric materials can be expressed as *R* is the electric resistivity (inverse of electric conductivity) and *k* is the total thermal conductivity. This figure-of-merit may be made dimensionless by multiplying by $\bar{T}$(average absolute temperature of hot and cold plates of the thermoelectric module, *K*), i.e.,

Maximum power output as a function of temperature differences. (a) Modules denoted I possess 127 thermocouples; (b) Modules denoted II possess 31 thermocouples and modules denoted III possess 50 thermocouples (more specifications are given in Table **1**

THERMOELECTRCI MATERIALS FOR POWER

Generator



Among the vast number of materials known to date, only a relatively few are identified as thermoelectric materials. As reported by Rowe, thermoelectric materials can be categorized into established (conventional) and new (novel) materials, Today's most thermoelectric materials, such as Bismuth Telluride (Bi2Te3)-based alloys and PbTe-based alloys, have a *ZT* value of around unity (at room temperature for Bi2Te3 and 500-700K for PbTe).

However, at a *ZT* of 2-3 range, thermoelectric power generators would become competitive with potential power generating applications relevant to solar energy. Effective thermo-electric materials should have a low thermal conductivity but a high electrical conductivity. A large amount of research in thermoelectric materials has focused on increasing the Seebeck coefficient and reducing the thermal conductivity, especially by manipulating the nanostructure of the thermo-electric materials. Because the thermal and electrical conductivity correlate with the charge carriers, new means must be introduced in order to conciliate the contradiction between high electrical conductivity and low thermal conductivity as indicated by Weiling and Shantung.

CONCLUSION

Integrating features of all the hardware components used have been developed in it. Presence of every module has been reasoned out and placed carefully, thus contributing to the best working of the unit. Secondly, using highly advanced IC's with the help of growing technology, the project has been successfully implemented.

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