Effect of temperature on the performance of Micro-TPVGenerator

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Abstract—This paper is an attempt to work on the waste heat cogeneration system. Waste heat contained basically a low energy in it. This heat is wasted due to low level energy contain. In this paper a study regarding the temperature effect of the source on the performance are being studied. A prototype micro-thermophotovoltaic (micro-TPV) power generator is taken for the study.Our system is consisted of the following component An emitter made up of SiC,a six layered filter as an insulation, Gallium antimonite PV cell array . When Hydrogen flows through the combustion chamber then an air and hydrogen ratio is maintained about 0.96 appx. It has been observed that an electrical power is obtained in the range of 0.97-1.002W .A combustion chamber of 114m^3 of volume is taken for the study.It is also observed that PV array may be replaced with other material to improved the electrical power output. V_{oc} and I_{sc} are obtained in the range of 2.319-2.14V and 0.499-0.53 A respectively.

Keywords—GaSb PV array,SiC emitter,Micro combustor, TPV Micro generator

I. INTRODUCTION

An electrical power out put from the utilization of waste heat is obtained through a concept of Thermo-photovoltaic generator (TPV).In this innovation a photovoltaic array of cells are used A schematic of TPV is presented in the Figure 1, in the figure main constituent elements and flow of energy is shown in the term of line diagram.

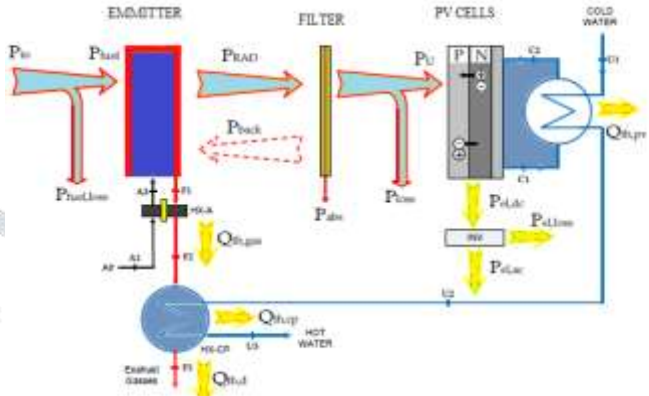

Fig.1.1Schematic of TPV generator

It is shown in the fig. that A ThermoPhotovoltaic generator made up of source of heat, a filter and a photovoltaic cells array; an air pre-heating system for the combustion is also drawn in the Figure 1.1. The heat obtained through the TPV is recognized by the heat obtained through the cooling of PV cells in the heat exchanger unit or coil and combustion products obtained by the combustion of fuel.

The TPV system is a cogeneration of heat system in which the waste heat is utilized and recovered the energy from it. So the system is beneficial in the following aspects:

(*i*) It is becoming a dual system as the heat producing and waste heat utilizing in the power generation system so it is providing the high fuel utilization factor ≈1, (*ii*) Noise levels is minimized, (*iii*) maintenance is easy due to the absence of dynamic parts in the system.

and (*iv*)Flexible for various fuels like; fossil fuels (natural gas, oil, coke, etc.) domestic wastes, nuclear fuels, etc; Solar insolation can be concentrated through parabolic trough or concentrators may also be used as a TPV heat source [1-3]. A TPV system produces a very low or nil amount of pollutant emissions in the terms of particulates emittants of carbon monoxide and Nitrous oxide. The main application of TPV system is in the devices where the preheating air or gas is required though it is generally keyed

with combustion devices such as domestic boilers. Some more applications of TPV system can be discussed here as in the automobile sector in case of hybrid vehicles [4], or in the industries where high high temperatures is to be required [6]. So the TPV system can be recognized and used as a small generators [7, 8], waste heat co-generation systems [9], combined thermal power plants and solar power plants [10], on grid system [11] independent device [12]. Other literature shows that the TPV generator can be equipped with the thermo-electric power systems [13] in the military and space sectors [14-19].
The electrical efficiency of a TPV generator can be written as:

$$\eta_{EL,TPV} = \eta_{CC} \cdot \eta_{RAD} \cdot \eta_{GAP} \cdot \eta_{F} \cdot \eta_{VF} \cdot \eta_{PV} \cdot \eta_{dc/ac}$$

where:

η_{CC}: combustion efficiency;
ηRAD: radiant efficiency;
ηGAP: spectral efficiency;
ηF: filter efficiency;
ηVF: view factor efficiency
$\eta Cell$: cell efficiency
$\eta inverter$: Inverter efficiency.

II.LITERATURE SURVEY

Studies shows that the work were carried out on the TPV has been started in the early years of 1960[20, 21], but in the last decade research on the TPV has been accelerated markedly along with the research on PV solar array.
The basic research pointed towards the incremented electrical efficiency and it is found that the electrical efficiency of the several prototypes [19, 22-27] observed in the range of 0.67% to 24%.Moreover, prototype has been developed for waste heat recovery system.
As our work is related with the development of a prototype of micro TPV Generators and its performance evaluation with the use of concentrated sunlight and an artificial combustion chamber. So in this way various prototype models are studied. Among which the most relevant research groups are the CANMET Energy Technology Centre, the Paul Scherrer Institute, and the JX Crystals Inc [90-92]. The main results of the developed prototype is reported as the electrical power the values of which is ranging from >10 W to about 3 kW. [90-92]. In Figure 3 (a), the electrical efficiency of the different prototypes with the electrical power output is presented [90-92];

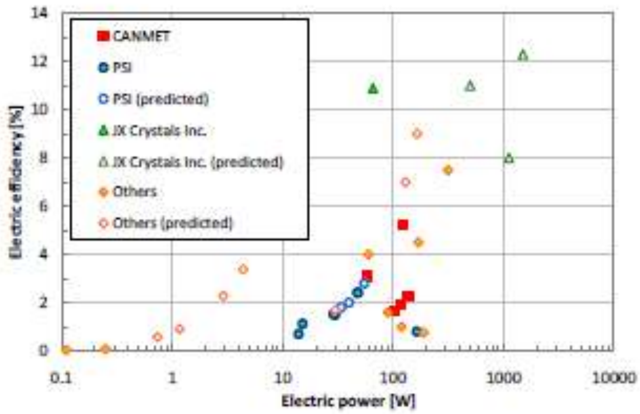

Fig.2.1Variation of electric efficiency with the electric power of TPV prototypes

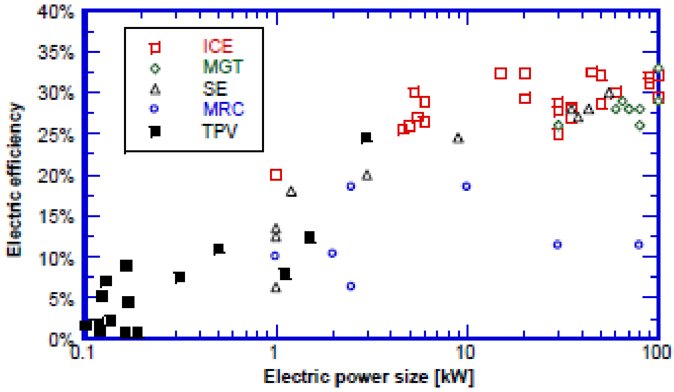

Fig.2.2Comparison of TPV performance to conventional system

Figure 2.1 and 2.2compares the values of TPV performance in terms of Electrical power and Electrical efficiency with the conventional CHP type. TPV secure the field of electrical power output which is < 1-2 kW it shows the conversion efficiency appx. 10%.

III.TEMPERATURE EFFECTS

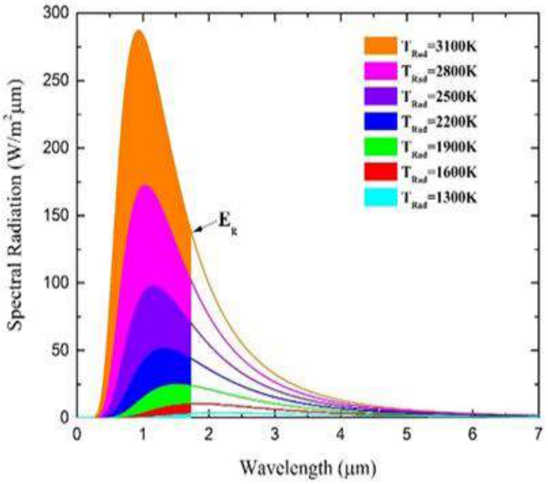

Fig.3.1 Variation in the spectral radiation according to the radiation temperature.

Figure 3.1 shows the variation of spectral radiation at different wavelengths which depends on the various radiation temperature.It is found from the figure that as the wavelength increases ,the spectral radiation decreases. For instance, at a radiation temperature of 2800 K, the spectral radiation at 1 µm wavelength is approximately 170W / m² µm, while it decreased to approximately 75 W / m² µm at 2 µm wavelength. For other temperature at 2500 K the spectral radiation at 1 µm wavelength is approximately 100W / m² µm, while it decreased to approximately 50 W / m² µm at 2 µm wavelength. At 2200K the spectral radiation at 1 µm wavelength is approximately 50W / m² µm, while it drops down to approximately 25 W / m² µm at 2 µm wavelength. At 1300K the spectral radiation at 1 µm wavelength is approximately 10W / m² µm, while it drops down to approximately 5 W / m² µm at 2 µm wavelength In this case, as the wavelength increases, the spectral radiation decreases.

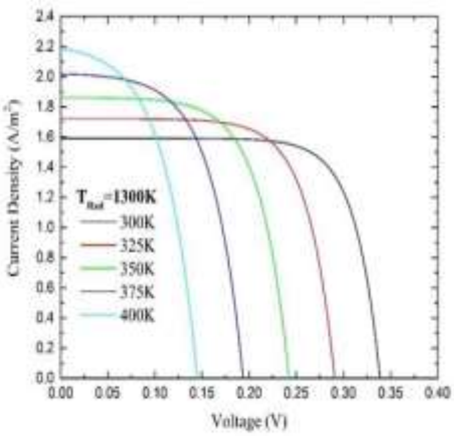

Fig.3.2 Variation of current density with the Voltage according to cell

Figure 3.2 shows as the voltage increases current desities decreases, at radiation temperature 1300K. current density is 1.6 A/m² while voltage varies from 0 to 0.35 V at different cell temperatures current densities varies accordingly for example at 400 K temperature voltage values from 0 to 0.15 V the current density is2.2 A/m² and so on.

Figure 3.3 shows current densities at 2500 K radiation temperatures versus varying voltage values at different cell temperatures. For example, at 375 K cell temperature, current density is 97 A / m² while the voltage value is 0.1 V, whereas when the voltage value is 0.3 V, the current density drops to about 45 A / m².

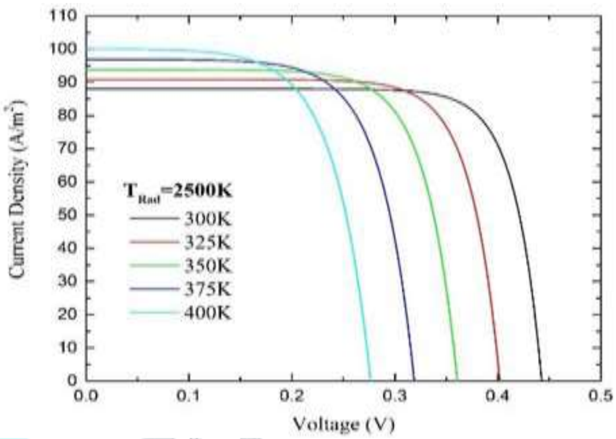

Fig.3.3 Variation of current density with the Voltage according to cell

IV RESULT AND DISCUSSION

To observe the effects of temperature on the performance of the TPV micro generator prototype, GaSb PV circuit is taken and for solar radiation a flash lamp solar simulator has been used. The results are shown below in the graphical manner.

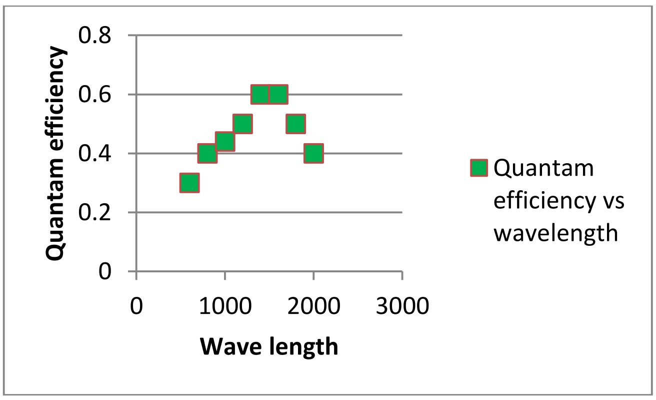

Figure 3.4. Quantum efficiency of GaSb PV cells.

FF=0.778
VOC=2.89 Volts

Isc=1.65 Amps
Imax=1.534 Amps
Vmax=2.41 Volts
Pmax=3.63 Watts

Fi.3.4 shows the Quantam efficiency of the Galium antimonide PV array with the variation of wavelength of incoming radiation.It is clearly shown in the figure that Quantam efficiency increases with the increase of wavelength.After achieving the maximum efficiency which is about60% at wavelength 1500nm it drops down.
Galium antimonide PV array produces a very good conversion effect and the value of Fill Factor reaches upto 0.778 which seems better for its commercial use.

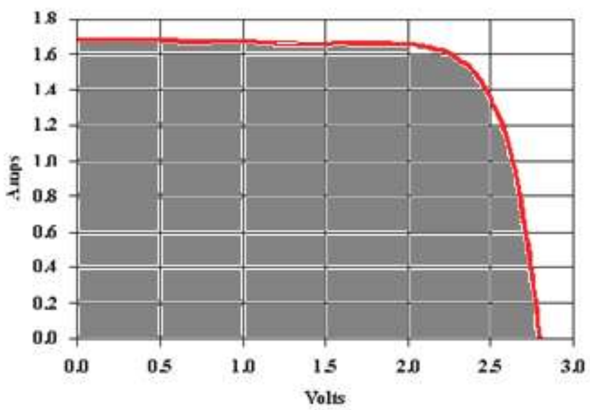

Figure 3.5 I–V curve of the GaSb PV array

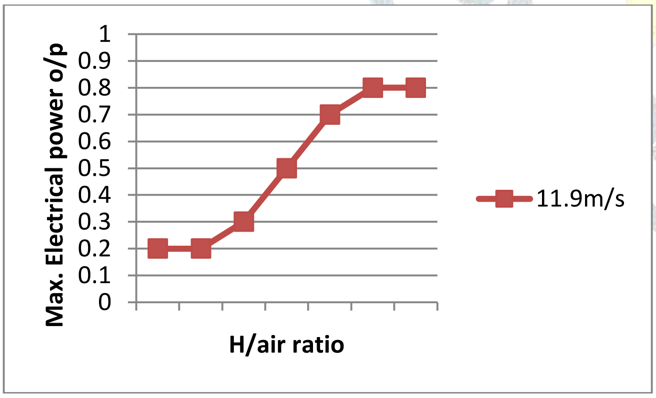

Figure 3.6 The maximum electrical power output under Max. H2/air ratios and flow rates.

The *V-I* characteristic curve of the PV circuit is shown in figure 3.5. A very well defined parabolic curve is obtained. By adjusting the light intensity a required amount of current density is may be achieved.
In our project we are going to measure the electrical power out put for the various flow rate of hydrogen or methane as a fuel. In this paper the maximum hydrogen flow rate is observed which is equais 11.9m/s. At this flow rate maximum electrical power is obtained. Furthermore at various hydrogen flow rate and methane flow rate electrical power will be compared.Figure3.6 shows the maximum electrical power output for 11.9 m/s hydrogen flowrate and at various H2/air ratios. It has been observed from the fig.3.6 that With the increase in the flow rate and the H2/air ratio, the maximum electrical power output increases drastically. This is due to a heavy amount of fuel is used in the combustion.

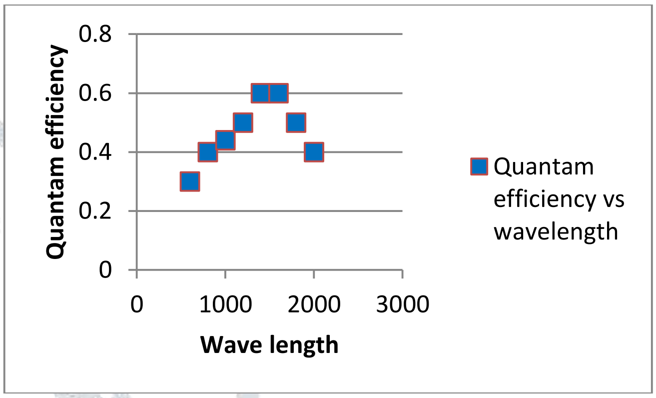

Figure 3.7. Quantum efficiency of GaInAsSb PV cells.

When Hydrogen flows through the combustion chamber then an air and hydrogen ratio is maintained about 0.96 appx. It has been observed that an electrical power is obtained in the range of 0.97-1.002W .the micro-TPV system, corresponding to an overall efficiency of 0.66%, which is eight times that obtained by Nielsen [17]. .It is also observed that PV array may be replaced with other material to improved the electrical power output. V_{oc} and I_{sc} are obtained in the range of 2.319-2.14V and 0.499-0.53 A respectively.
In the micro-SiC flame tube combustor experiment discussed above,we noticed that the temperature along the wall of the micro-combustor is only 1300 K. At this temperature, if we substituted the GaSb PV cells with GaInAsSb PV cells, the efficiency of the micro-TPV power generator can be further enhanced due to the lower band gap of the GaInAsSb PV cells. Figure 3.7 shows the quantum efficiency of GaInAsSb PV cells.
GaInAsSbhas been used by other researchers [18],and an electrical power output of 1.45W can be achieved, if a GaInAsSb PV cell array is employed in the design of micro-TPV power generators. The efficiency will be more in

comparison with the GaSb PV cell array. Generally GaSb PV cell array are available for the commercial application at the cheap rates so we have employed this array but it can be further replaced with the GaInAsSb PV cells. Instead of using simple filter, an optical filter with various layers can be used or a selective filter can also be employed to improve the electrical power output.In order to further improve the efficiency of the micro-TPV system, it is necessary to employ a selective emitter. For future applications photons located in the short wavelength range with energy greater than the bandgap of PV cells different emitter can be used in place of SiC.Furthermore, there is also a much place for the improvement of obtained efficiency from the TPV system, Although here an efficiency in the range of 18.3% to 19.5% may be achieved from our design.

IV CONCLUDING REMARK

In this paper a study regarding the temperature effect of the source on the performance are being studied. A prototype micro-thermophotovoltaic (micro-TPV) power generator is taken for the study.Our system is consisted of the following component An emitter made up of SiC,a six layered filter as an insulation,Galium antimonide PV cell array . When Hydrogen flows through the combustion chamber then an air and hydrogen ratio is maintained about 0.96 appx. It has been observed that an electrical power is obtained in the range of 0.97-1.002W .A combustion chamber of 114m^3 of volume is taken for the study.It is also observed that PV array may be replaced with other material to improved the electrical power output. V_{oc} and I_{sc} are obtained in the range of 2.319-2.14V and 0.499-0.53 A respectively.

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