Power Generation Using PV Cell and Thermoelectric Generation

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Abstract - *In the current world, the use of conventional sources is the most important task to be done. The increase in use of conventional sources not only provides energy for us but also provide green hazardless safe environment. Solar energy is an important source of expandable renewable natural energy resources. The paper presents a efficient use of solar energy harvesting techniques and methods to improve the energy conversion level with a photovoltaic cell and thermoelectric generator.*

Key Words: Solar energy, Seebeck effect, Photovoltaic (PV), Thermoelectric generator (TEG)

1.INTRODUCTION

This Increasing demand of fossil fuels leads to find other alternate source for power generation. Sun radiates an enormous amount of energy and comprises of hydrogen and helium gas. Photovoltaic cell converts only a part of solar energy and the rest remains as heat. Solar energy is a free energy and is available in most locations of the world. Power received from the sun is higher than all other energy sources and is approximately 1.8 X 1011 MW. In modern power generation harvesting the solar energy requires photovoltaic or installing large scale solar energy. Converting light energy into electrical energy depends on the photovoltaic system through the use of solar cells. Silicon in pure crystalline form is essential in PV cell and has some special properties but is not a good conductor; hence to make silicon in solar panels to conduct, impurities are added to silicon. Due to this reason silicon panel is preferred. Photovoltaic is scalable but not efficient, hence they are used in micro and macro level of power production. Heat energy of the sun is harvested by the solar thermal installations. Due to the low temperature of the solar energy they are not used for generation of energy. Flux of the solar radiation is 1kWh/m and the total radiation is below 7kWh/m in most of the hottest regions. Sunlight hits the PV cell which converts about 15% to electricity. The rest of the light about 85%, is converted into heat that passes through the Seebeck TEG, 1% or a bit more which produces more electricity, and the left over is heat rejected to the environment.

2. LITERATURE SURVEY

Methods to improve the efficiency of photovoltaic systems have been studied by many scientists and engineers and prescribed in general, to increase the efficiency of photovoltaic systems is by increasing the of power generation of the solar cells, also through deploying effective control algorithms for the energy conversion and to adopt a solar tracking mechanism. Recent studies and teaching have increased in the area of conventional energy utilization in recent years. A wide number of papers have emerged with considerable solutions, such as [3] and paper [4] describes some valuable photovoltaic panel solar tracker applications and their area of applicable feasibilities. In Paper [4] the potential system benefits of simple tracking of solar system design is implemented using a stepper motor and light sensor. In paper [7] a single-axis sun tracking system mechanism is proposed with two sensors was designed and the data acquisition, control and monitor of the mechanical movement of the photovoltaic module were implemented based on a programmable logic-controlling unit. To make the solar tracking mechanism effective the authors of paper [6] have presented the design and construction of a two axis solar-tracking system in order to track the photovoltaic solar panel according to the direction of solar radiation. In order to achieve maximum solar energy, system is generally equipped with functions which are calculating the maximum power point tracking (MPPT) as shown in [8 and 9]. Our work enhances with the considerations of previous related developments in solar energy harvesting.

3. PROPOSED SYSTEM

In this paper, a hybrid model is used in which heat energy is converted into electrical energy by using thermo electric generator. TEG recovers the waste heat and converts the heat energy into electricity based on seebeck effect. Small temperature differences and small heat sources are suitable for thermoelectric systems. Such generators are used in automotive for waste heat recovery and in home for heat and electricity generation. It is less efficient compared with other heat engines, hence TEG is suitable for small applications. Temperature gradient is the main consideration in the thermoelectric power generation. High temperature gradient leads to increase in output. The efficiency of TEG can be increased by adding photo voltaic cells above the generator. Thus efficient utilization of solar energy by a system that combines photo voltaic layer with thermoelectric generator on a solar tracking system is designed. Efficiency of a solar panel is improved by using the hybrid solar panel. A PV layer can attain maximum efficiency about 30%, this is increased by adding TEG layer to convert the waste heat energy to current, in this idea the combined PV layer and TEG layer is placed in the single axis solar tracking system, thereby increasing the efficiency much better.

4. WORKING AND BLOCK DIAGRAM

Earth receives the solar power as radiation or light; if it is combined together it is sufficient for all human being [1]. Existing method of converting solar energy into electricity provide 25% efficiency. This efficiency can be further improved by using solar thermal power with the photovoltaic. A temperature difference of at least 50 degree is needed for the thermoelectric device to work efficiently. Photovoltaic/thermoelectric (PV/TE) cell integration is a promising technology to improve performance and increase the cell life of PV cells. The concentrator fixed is used to heat the PV element, which increase the PV efficiency.

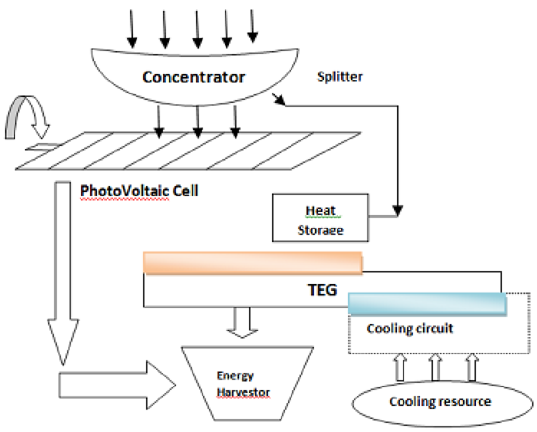

Figure 1. Block diagram of Hybrid PV and TE system

4.1 PV operation:

Step 1 :
A PV cell is made of a pure silicon wafer. The wafer is thinly diffused with n-type dopant and thickly with p type dopant such as phosphorous and boron on the top and bottom respectively. Compared with silicon, phosphorous has one more electron and boron has one less electron. When light falls on the PV cell, electrons move out of the cell due to the electric field created by the dopants. Phosphorous donates its excess electron to silicon because of the negative character, it is not charged and called as n-type silicon. P-type silicon is formed by gaining an electron from boron because of the positive character but is not positively charged.
Step 2:
A barrier of p-n junction is formed to control the flow of electrons in the n-region and p-region when n-type and p-type silicon meet. In p-n junction, p-type is negatively charged similarly n-type is positively charged due to the flow of electrons and holes. Flow of charges results in an electrical charge imbalance which produces electric field at the p-n junction.
Step 3:
Electrons in the p-n junction are energized when the photons of sun light the negative charge in the p-type silicon and attract towards the positive charge in the n type silicon. Hence at the silicon base collision of photoelectrons takes place.
Step 4:
A complete circuit is formed by which p-type silicon and n-type silicon is connected via electrical load (light or battery) by means of a conducting wire. Electron flow results in an electric current that flows from n-type silicon to p-type silicon. In addition to semiconductor solar cells consists of electrical contact and metallic grid. Metallic grid collects the electrons from semiconductor and transfers it to external load.

Conversely, the TE materials can be optimized to convert heat dissipated by the PV element into useful electric energy, particularly in locations where the PV cell experiences large temperature gradients, i.e. use the thermoelectric module terminals for cool and hot environment at both ends and energy generation depending on the ambient temperature varying conditions. When light strikes the surface of the solar panel, seebeck effect generates electricity due to the temperature difference. Pumping water through the cooling circuit is commonly used throughout the world which cools the TEG's other end. Combination of PV and
TEG which leads to hybrid system increases the efficiency by maintaining constant temperature. Capacitors are used to control the water pumps.

4.2 Solar Tracking:

Tracker is used to collect the maximum solar energy and to orient according to the position of the sun. Solar tracker orients the solar panel towards the sun. The angle of incidence between the sun light and the solar panel is minimized by the tracker for the flat panel. If the solar panel is placed horizontally, it cannot completely absorb the solar energy. To absorb the solar energy, solar panels are placed slanting, so that it can collect the solar energy more efficiently. Solar tracking have 50% of output energy in summer and 20% in winter. Based on several criteria such as rotation axes there are many solar tracking systems. Single axes solar tracking is preferred for the small PV plants . Electric motor and PV panel mount in the solar tracking system is used to adjust the panel according to the position of the sun. There are two components in sun light which includes direct beam and diffuse sunlight. Maximum of solar energy that is 90% is carried by direct beam and the remaining is carried by diffuse sunlight. Tracker should be placed such that it faces the direct beam.

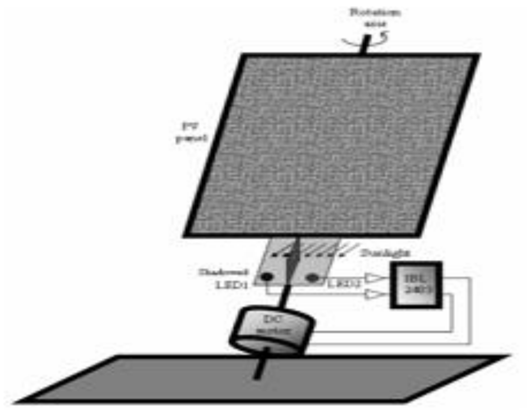

Figure 2. Principle of single axis solar tracker

In single axis solar tracker, tracking the sun is done from east to west. There are two LDR placed at each solar panel. LDR senses the sun light because it is made of cadmium sulphide. It is a variable resistor controlled by light. If the light intensity increases then the resistance will decrease. One of the LDR will be illuminated and the other will be shadowed based on the intensity of the sun light. The LDR which is illuminated make the panel to rotate in direction where the intensity of the sun is maximum. Tracking is done with the help of the solar collectors. Single axis tracker increases the output 30% compared with the fixed mount.

Intensity of the light is measured by the light intensity sensor. Light intensity sensor uses two LED to control the motion of the PV panel. LEDs are separated by a plate and placed above the PV panel. One LED will generate a strong signal and other LED will generate poor signal based on the position of the panel and the direction of sun light. Conversion efficiency of light into electricity is denoted by the strong signal generated by the LED. Use of light intensity sensor has advantages such as

1. If the light intensity is maximum the movement of panel is adjusted for consumption of maximum energy.
2. If the difference from two LED signals is large, the panel can be placed in a position such that it focuses the direction of sun.

Stepper motor is used to developed to rotate the PV and TEG setup mounted on the frame. The turning of the controlled is made by a timer IC which is triggers signals to drive the motor at an angle. The motor consumes 5 W power and it takes about 15s for each turning. The energy consumption of the driving motor is thus negligible. A rotating-type resistor was installed on the rotating axis as the position sensor to detect the angular position of the tracker to control the stopping angle. All the control algorithms, measuring functions for tracker motion and PV power generation, was implemented by the ARM micro-processor. Here microcontroller LPC2148 is used to build the system. To boost up the output voltage from the microcontroller in order to rotate the stepper motor, L293d IC is used. The instantaneous solar irradiation on the fixed PV with tilt angle 25degree is designed measured at every 3 s. The daily-total solar irradiation on the fixed PV tilt has to be integrated from measured value.

5. EFFICIENCY ANALYSIS

The ratio of the output of the solar cell and the incident sun light yields the solar cell efficiency similarly the ratio of the electrical energy to the solar energy gives the conversion efficiency. The heat Q is converted into power P by the thermoelectric generator with the efficiency η. The size of the heat exchangers determines the amount of heat Q that can be applied to the thermoelectric materials. Heat present in the hotter region is harvested. To obtain maximum power, heat exchangers used should be large compared with the thermoelectric generator.

$P = \eta Q$

Carnot heat engine will provide the maximum conversion efficiency of the sun light. Temperature difference determines the efficiency of a thermoelectric converter, but it is small compared with the Carnot cycle. Temperature difference is given by

$\Delta T = TH - TC$

Thermoelectric generator efficiency is

$$\eta=(\Delta T/TH)(\sqrt{(1+ZT)}-1/\sqrt{(1+ZT)}TC/TH$$

Where, $\Delta T/TH$ = Carnot efficiency

ZT = figure of merit

Calculation of thermoelectric generator is little complex where ZT is approximated by

$$ZT = \alpha 2T/\rho\kappa$$

Where, α= seebeck coefficient

ρ=electrical resistivity

κ=thermal conductivity

T=temperature

The total power is found to be the sum of individual PV and TEG.

$Ptot(T)=Qsolar\eta pv(T)+QTEG(T)\eta TEG(T)$

6. CONCLUSION AND FUTURE SCOPE

In this paper, a hybrid model of solar energy conversion system was proposed. Use of hybrid PV and TEG along with the single axis solar tracker is more efficient than using a single PV or TEG. By combining the solar tracking system with the hybrid PV and TEG system. There by increases the efficiency. In this work, we have presented solar into electrical conversion using thermoelectric and photovoltaic. The designed single axes solar tracking system has an advantage as it is simple to construct and easy to control. It provides an opportunity for improvement of the design methodology to set up in future.

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