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Implementation of CPV Cell for Electricity and Water Heating Using Dish Concentrator

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Abstract – The main aim of this study is to design and analyze the performance of water cooled concentrated photovoltaic cell and utilize the extracted heat for domestic purpose. Temperature characteristic analysis of the triple-junction solar cell was carried out using circuit simulator under concentration conditions. The temperature exponent of saturation current density for each single-junction solar cell was derived. Extracted temperature exponents were used in the equivalent circuit model for the triple-junction solar cell, and the calculations of solar cell performance were carried out at various temperatures and concentration ratios. The calculation results agreed well with the measured results. Today, in non-convectional and convectional energy sources The PDSC (Parabolic Dish Solar Collector) technology is very useful as it is used for approximately all solar energy applications such as steam and power generation, water heating, air heating etc. In this paper work the evaluation, comparison, and optimum selection of a PDSC system from the different alternative designs available in the global market is done with the use of systems approach the maximum number of attributes of the PDSC system are identified in an exhaustive way and classified under different categories. The attributes are identified taking into account all the factors i.e. performance, design, materials, cost, quality etc. that affect the PDSC system and are listed in a tabular form. The ranking and optimum selection of PDSC is done by the use of a mathematical technique and also by line graph representation from review papers.

1. INTRODUCTION

1.1 SOLARENERGY

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever- evolving technologies such as solar heating, photo-voltaic, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis.

It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

The Earth receives 174,000 terawatts (TW) of incoming solar radiation (insulation at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet. Most of the world's population lives in areas with insulation levels of 150-300 watts/m², or 3.5-7.0 kWh/m² per day.

1.2 SOLAR POWER

Solar power is the conversion of energy from sunlight into electricity, either directly using photo voltaic (PV), or indirectly using concentrated solar power. Concentrated solar power systems uses lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect.

Photo-voltaic were initially solely used as a source of electricity for small and medium- sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV system. Commercial concentrated solar power plants were first developed in the 1980s. The 392 MW Ivanpah installation is the largest concentrating solar power plant in the world, located in the Mojave Desert of California.

1.3 PHOTO-VOLTAICS

A solar cell, or photovoltaic cell (PV), is a device that converts light into electric current using the photovoltaic effect. The first solar cell was constructed by Charles Fritts in the1880s. The German industrialist Ernst Werner von Siemens was among those who recognized the importance of this discovery. In 1931, the German engineer Bruno Lange developed a photo cell using silver serenade in place of copper oxide, although the prototype selenium cells converted less than 1% of incident light into electricity. Following the work of Russell Ohl in the 1940s, researchers Gerald Pearson, Calvin Fuller and Daryl

Chapin created the silicon solar cell in 1954. These early solar cells cost 286 USD/watt and reached efficiencies of 4.5–6%.

1.4 CONCENTRATED PV SYSTEMS

The array of a photovoltaic power system, or PV system, produces direct current (DC) power which fluctuates with the sunlight's intensity. For practical use this usually requires conversion to certain desired voltages or alternating current (AC), through the use of inverters. Multiple solar cells are connected inside modules. Modules are wired together to form arrays, then tied to an inverter, which produces power at the desired voltage, and for AC, the desired frequency/phase.

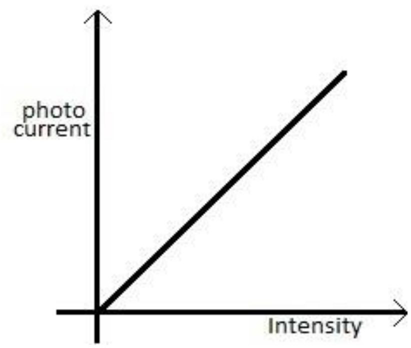


Figure: Graph between intensity and photo current

Many residential PV systems are connected to the grid wherever available, especially in developed countries with large markets. In these grid-connected PV systems, use of energy storage is optional. In certain applications such as satellites, lighthouses, or in developing countries, batteries or additional power generators are often added as back-ups. Such stand-alone power systems permit operations at night and at other times of *limited sunlight.*

1.5 CONCENTRATED SOLAR POWER

Concentrated solar power (CSP), also called "concentrated solar thermal", uses lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Contrary to photo-voltaic – which converts light directly into electricity – CSP uses the heat of the sun's radiation to generate electricity from conventional steam-driven turbines.

A wide range of concentrating technologies exists: among the best known are the parabolic trough, the compact linear Fresnel reflector, the Sterling dish and the solar power tower. Various techniques are used to track the sun and focus light. In all of these systems a working fluid is heated by the concentrated sunlight, and is then used for power generation or energy storage. Thermal storage efficiently allows up to 24-hour electricity generation.

A parabolic trough consists of a linear parabolic reflector that concentrates light onto a receiver positioned along the reflector's focal line. The receiver is a tube positioned right above the middle of the parabolic mirror and is filled with a working fluid. The reflector is made to follow the sun during daylight hours by tracking along a single axis. Parabolic trough systems provide the best land-use factor of any solar technology. The SEGS plants in California and Acciona's Nevada Solar One near Boulder City, Nevada are representatives of this technology.

Compact Linear Fresnel Reflectors are CSP-plants which use many thin mirror strips instead of parabolic mirrors to concentrate sunlight onto two tubes with working fluid. This has the advantage that flat mirrors can be used which are much cheaper than parabolic mirrors, and that more reflectors can be placed in the same amount of space, allowing more of the available sunlight to be used. Concentrating linear Fresnel reflectors can be used in either large or more compact plants.

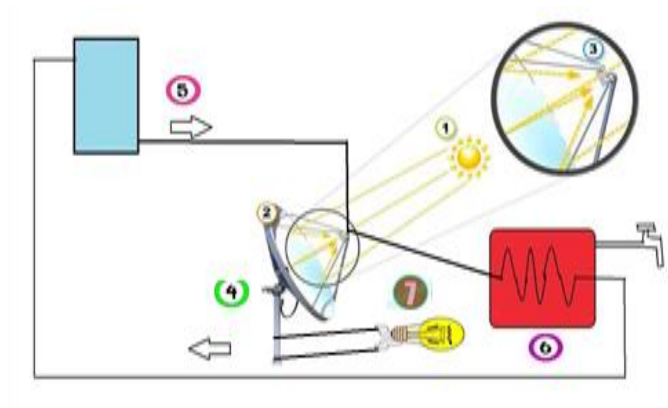


Fig.: Experimental set up

The experimental setup consists of a dish concentrator which is fitted with a concentrated photovoltaic cell and heat sink at its focal point. heat sink is then connected to heat exchanger with the help of pipe to remove heat water from heat sink to cool cpv cells, reservoir to store hot and cold water. Battery to store electricity from CPV cells.

2. MATERIALS AND SPECIFICATIONS

Materials required

2.2.1Parabolic dish concentrator

2.2.2Aluminum Heat sink

2.2.3Copper coil heat exchanger

2.2.4Concentrated photovoltaic cell

2.2.5Worm gear

2.2.6Passive water cooling system

2.2.7Battery

The ability to compute a high-resolution 3D model of the reflector surface at anytime of the year allows for detailed retracing analyses of the sunlight converging at the focus. By applying various types of deviation to the surface to simulate manufacturing inaccuracies or imperfections it is possible to calculate the size of the focus and the power delivered to a certain area.

Figure: Dishconcentrator

For the purposes of a Scheffler concentrator with cooking applications a focus area of about 15 cm by15 comes considered to be a reasonable target. Two Matlab functions we recreated for retracing analysis. The first compares the difference in angle and position between the theoretical shape and a slightly deformed shape. The second is a global retracing code that traces rays from any direction though a reflection from an arbitrarily shaped surface with a square mesh.

2.2.1 ALUMINIUM HEAT SINK

As high-power electronic devices dissipate more power and face new constraints due to space and weight limitations, liquid cooling seems to offer a superior alternative for systems traditionally equipped with air cooling. Cooling of high-power electronic devices poses some unique challenges that are somewhat different from those in IC chip cooling. The combination of high heat flux and high power requirements necessitates efficient thermal and fluid management in the heat sink. Some of the overriding design considerations are:

• Temperature and heat dissipation requirements of each individual device (simultaneous peak load of relevant components in a group).

• Pressure drop and flow rate requirements for the cooling fluid. In designing a cold plate,

the designer works with a given set of inlet fluid temperature, mass flow rate, and pressure drop limits, as well as individual device power dissipations and junction temperature requirements, and placement of devices relative to each other. The design of individual devices and the thermal

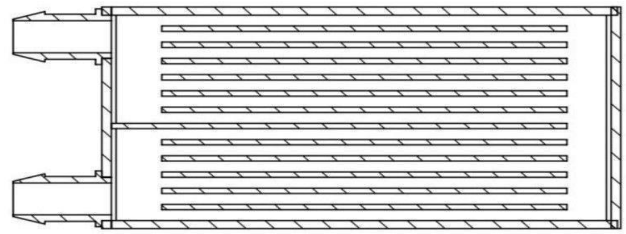


Figure: Heat sink basic diagram

Heat sink is used to extract heat from the concentrated photo-voltaic to keep it cool. The water is passed through the pipe from the reservoir with multi-pass flow and the heat is extracted. Temperature will take a drop as cool water takes down heat and heated water is sent to heat exchanger to cool it further.

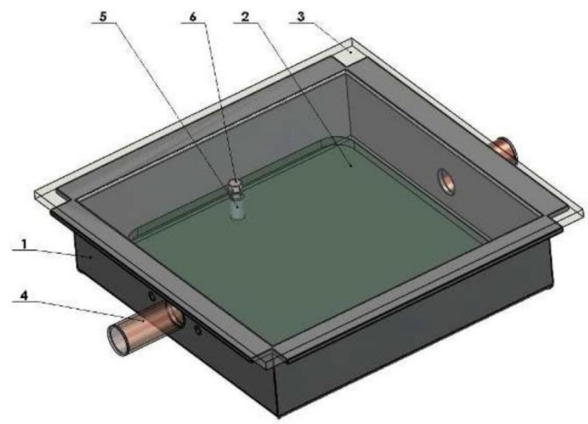


Figure: Heat Sink Design

The Heat Sink consists of two pipes inlet and outlet, CPV cell is placed at bottom and glass plate to cover cpv with fins for natural convection on the other side.

Figure: Fins on heat sink

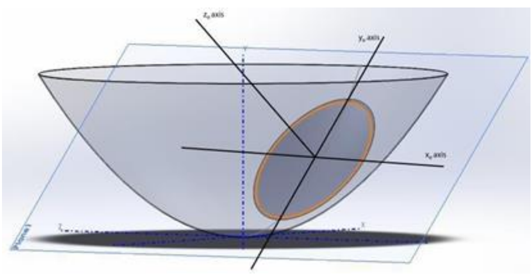
3. METHODOLOGY

The methodology of this project involves designing, modeling, fabrication work, determination of suitable specification of dish concentrator, tracking unit, heat exchanger heat sink, concentrated photovoltaic cells and testing results like thermal efficiency cooling efficiency, electrical output and thermal output, ray analysis, dish analysis etc.,. And also optimizing some different operating parameters like thermal insulation, tracking mechanism, initial inclination angle that dish concentrator faces the sun, optimizing of focusing sun light and study of various case study of the technologies related to concentrating solar power.

The design of heat exchanger, heat sink, ray tracing analysis, analysis of temperature distribution of heat sink and heat exchanger are made using SOLID works V5 software package. Fabrication of the whole unit is pretty straight forward and involves metal cutting, welding, drilling holes etc. calculations are done using suitable formulas referred from various books.

4. DESIGN AND ANALYSIS

4.1 DISH CONCENTRATOR DESIGN



5. RESULT AND DISCUSSION

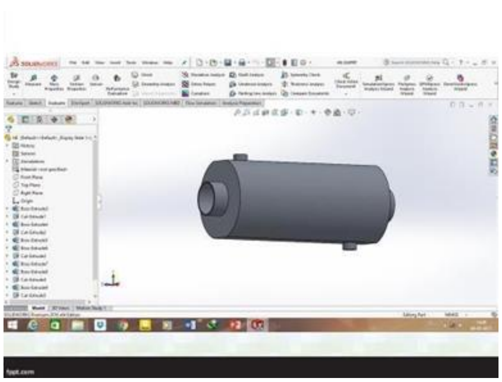


Figure : 3D model of heat exchanger

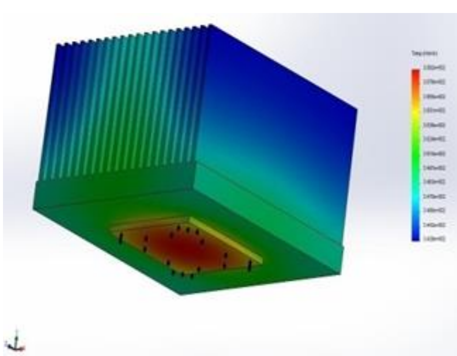


Figure: Heat sink model with analysis

6. CONCLUSION

- The project model is capable of producing electricity using Concentrated photovoltaic (CPV) during sunny day and Photovoltaic (PV) during cloudy day.
- It simultaneously extract the heat from solar receiver thus utilizing 95% of sun ‘radiation.
- The intent for this project was a combination of research, analysis, design, and project management.
- The four goals of developing in-depth understanding of the Scheffler reflector dynamics, analyze the sensitivity of the focus to deformations and deviations, to design a reflector constructed from accessible materials, and to drive the raw material and manufacturing down were all successfully advanced.
- Much more work is left to be done before the Cal Poly Scheffler Reflector group can deploy their design in developing nations, but new students are already building upon the advancements we accomplished in 2012-2014.
- A strong analysis tool was able to improve on our understanding of the dynamics of our solar concentrator.
- The sensitivity analysis brought a quantitative level of understanding of the manufacturing tolerances and quality required to produce a high quality concentrator.
- We were also able to explore various permutations of the design.
- Most importantly, this analysis and the foam mold allowed for the creation of various new prototypes and laid the foundation for new manufacturing methods of the parabolic dish.
- A total of three different reflector prototypes were created from very different materials and techniques.
- The wooden reflector proved that with good design and manufacturing technique, a reflector can be made with very simple materials and without high tech machining hardware.

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