ENHANCEMENT AND DESIGN OF COOLING SYSTEM FOR A CONCENTRATING PHOTOVOLTAIC (CPV) SOLAR CELL IN A PARABOLIC DISH COLLECTOR SYSTEM

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Abstract— Now-a-days concentrated photovoltaic cell (CPV) is one of the promising technologies to convert solar radiation to electricity. The main task involved in the concentrated photovoltaic system is to track the sun and to focus the solar radiation onto the concentrated photovoltaic cell. Focusing the solar radiation on to the solar cell increases the cell temperature, which deteriorates the performance of the solar cell. In order to overcome this problem, an efficient cooling technology can be adopted in the concentrated photovoltaic system to remove the thermal heat efficiently and to increase the performance of solar cell. In this project, low cost nanofluid cooling technology is implemented in the concentrated photovoltaic solar cell for performance enhancement.

Keywords— Concentrated Photovoltaic cell, Cooling system,Solar Parabolic dish, Nano Fluid receiver box.

I. INTRODUCTION

Survival without Energy is a tough job, but at the same time, speculations still exists whether there is any other candidate for a planet other than the earth. This calls for an alternative source of Energy. Renewable energy is simple enough-formed by resources which are naturally replenished. This includes sunlight, wind, tides, geothermal, etc. There are diverse reasons that make renewable energy stand apart from other forms of energy. Implementation of renewable energy decreases the greenhouse gases levels, boosts our economy in the form of new jobs, improves energy security by reducing the foreign import of oil and many more. Among the different sources, our Sun is one such which has almost unlimited potential.

Every day the sun radiates massive amount of heat. Only less amount of sunlight strikes the earth surface. Harnessing Sun's energy is not a recent invention, it dates centuries back .It started with concentrating sunlight with glass and mirrors to light fires. But it is not a easy task, since the small amount of energy that reaches the earth's top is in diffused form. The amount of radiation a area receives depends on the hour of the day, season of the year, clouds in the sky and how near we are to the equator. There are many ways to capture sunlight. Few of them are, solar collectors, solar space heating, solar water heating. The principle of all is same and simple. The sunlight is collected inside a box, a car or a room which is covered by glass. The walls, floors and the seat covers absorb the heat, but they do not let it out. This collected heat can be later used for heating water and other chores.

Solar energy can also be used to produce electricity. This can be achieved in two ways-Photovoltaic systems and concentrated solar systems.

Photovoltaic comes from the words photo, which means light, and volt, which is a measurement of electricity. Photovoltaic (PV) solar cells directly convert sunlight into electricity, using the photovoltaic effect, i.e. creation of voltage or current on exposure to sunlight. PV power has an enormous energy potential and is usually seen as an environmentally benign technology thin film crystalline silicon (c-Si) technology dominate the global PV market. In a c-Si PV system slices (wafers) of solar-grade (high purity) silicon are made into cells that are assembled into modules and electrically connected. Crystalline silicon PV is the oldest and currently dominant PV technology with approximately 85-90% of the PV market share. Conversion efficiency, defined as the ratio between the produced electrical power and the amount of incident solar energy per second, is one of the main performance indicators of PV cells and modules

Over the years a good number of countries have implemented specific policies and incentives to support PV deployment. This has led to a rapid increase in the total installed capacity of PV from 1.4 GW in 2000 to around 70 GW at the end of 2011, with about 30 GW of capacity installed in that year alone. The associated industrial learning and market competition have resulted in very significant and rapid cost reductions for PV systems. Continued cost reductions for PV systems are an

essential requirement for accelerating the attainment of grid-parity of electricity generated using on-grid solar PV systems. In countries with good solar resources and high electricity tariff s, residential solar PV systems have already reached parity with electricity retail prices, whilst in general PV is now fully competitive with power generated from diesel-based on- and off -grid systems.

The choice of solar PV technology for installation is often based on a trade-off between investment cost, module efficiency and electricity tariff s. Compared with c-Si-based PV systems, the production of TF PV system is less energy-intensive and requires significantly less active (semiconducting) material. TF solar PV is therefore generally cheaper, though significantly less efficient and requires substantially more surface area for the same power output, than c-Si-based systems. The module cost of c-Si PV systems have fallen by more than 60% over the last two years; in September 2012, Chinese-made modules averaged USD 0.75/watt, while TF PV modules. Consequently, even though TF PV has experienced tremendous growth a few years ago, more recently its market share is decreasing and the current outlook for further growth in the deployment of this technology is uncertain and will depend heavily on technology innovation. This invention was also followed by few drawbacks. The biggest disadvantage of PV system is its low efficiency levels. The highest efficiency experienced till date is around 25%.The final output given out by the cell is in DC from which has to be converted into AC using Inverters, which further adds up to the cost. One of the main drawback was its inability to store excess electricity during the nights. This greatly influences the financial performance of PV investment. Also the PV output is intermittent.

All these hindrances led the way for Concentrating Solar Systems. Concentrator Photovoltaic (CPV) is a technology that uses optics such as lenses or curved mirrors to concentrate a large amount of sunlight onto a small area of solar photovoltaic cells to generate electricity. The key benefits of CSP over PV are, it is 3-4 times more efficient than the traditional PV or thin film modules, consists of an intelligent two-axis tracking system to provide maximum energy yield, requires less amount of semiconductor material, makes use of highly efficient but expensive multi-junction cells which further reduces the cell area requirement.

All CPV systems have a concentrating optic and a solar cell. Except for very low concentrations, active solar tracking is also necessary. Low concentration systems often have a simple booster reflector, which can increase solar electric output by over 30% from that of non-concentrator PV systems.

Semiconductor properties allow solar cells to operate more efficiently in concentrated light, as long as the cell Junction temperature is kept cool by suitable heat sinks. Efficiency of multi junction photovoltaic cells developed in research is upward of 44% today, with the potential to approach 50% in the coming years.

Also crucial to the efficiency and cost of a CPV system is the concentrating optic since it collects and concentrates sunlight onto the solar cell. For a given concentration, non-imaging optics combine the widest possible acceptance angles with high efficiency and, therefore, are the most appropriate for use in solar concentration. For very low concentrations, the wide acceptance angles of non-imaging optics avoid the need for active solar tracking. For medium and high concentrations, a wide acceptance angle can be seen as a measure of how tolerant the optic is to imperfections in the whole system. It is vital to start with a wide acceptance angle since it must be able to accommodate tracking errors, movements of the system due to wind, imperfectly manufactured optics, imperfectly assembled components, finite stiffness of the supporting structure or its deformation due to aging, among other factors. All of these reduce the initial acceptance angle and, after they are all factored in, the system must still be able to capture the finite angular aperture of sunlight.

CSP technology utilizes three alternative technological approaches: trough systems, power tower systems, and dish/engine systems.

Trough Systems:

Trough systems use large, U-shaped (parabolic) reflectors (focusing mirrors) that have oil-filled pipes running along their center, or focal point. The mirrored reflectors are tilted toward the sun, and focus sunlight on the pipes to heat the oil inside to as much as 750°F.

Power Tower Systems:

Power tower systems also called central receivers, use many large, flat heliostats (mirrors) to track the sun and focus its rays onto a receiver. The receiver sits on top of a tall tower in which concentrated sunlight heats a fluid, such as molten salt, at a temperature of 1,050°F.

Dish Systems:

Dish systems use mirrored dishes to focus and concentrate sunlight onto a receiver. The receiver is mounted at the focal point of the dish. To capture the maximum amount of solar energy, the dish assembly tracks the sun across the sky. Our main focus here is on Dish type systems.

The main constraint in the success of CPV technology is heating of cell which increases the temperature and thus the efficiency of the cell reduces. This calls for the need for proper design of heat sink.

Many works have been proposed in this aspect but due to high initial cost, the practical implementation is yet to be done.

This Report introduces you to a low cost cooling technique to extract heat from the cell and maintain the CPV cell temperature to a safe level and thus achieving increment in its efficiency.

The main problem in the CPV technology is the increase in cell temperature which in turn decreases its efficiency. The open circuit voltage (Voc) decreases with increase in temperature. Following the decrease in Voc ,the overall cell efficiency decreases almost linearly with the temperature of the material, for a given light flux. Numerous people have put forth interesting work and have done significant research in this area. Various methods have been proposed to achieve significant drop in cell temperature and maintain it to a safe and uniform limit.

II. DESIGN OF SOLAR PARABOLIC DISH

Now a parabolic reflector is a reflective surface used to collect or project energy such as light, sound, or radio waves. Parabolic reflectors are used to collect energy from a distant source and bring it to a common focal point, thus correcting spherical aberration found in simpler spherical reflectors. There are two key phenomena to understand the design of parabolic dish. One is that the shape of the parabola is defined such that incoming rays which are parallel to the dish's axis will be reflected towards the focus. The second phenomenon is that the light rays from the sun arriving the earth's surface are almost completely parallel. So if dish can be aligned with its axis pointing at the sun, the incoming radiation will almost all be reflected towards the focal point of the dish-most losses are due the imperfection in the parabolic shape and imperfect reflection.

2.1 Design of Solar Parabolic Dish Concentrator:

In Aperture area of the dish   : $2.5 \ m^2$
Rim angle of the dish (Φ)   : 60^0
Reflectivity of the dish   :   0.95
Receiver intercept factor   :   0.95
    Diameter of the dish
        $\Pi r^2 = 2.5$
        $r = 0.8920 \ m$
Diameter of the dish (d)   : 1.7841 m
    Focal length of the dish
        f= 0.77254 m
Focal length of parabolic dish   : 0.77254 m
    Solar image width (Ideal)
    Ideal solar image: 1.917 cm
    Depth of the parabolic dish:
        h= 0.2575m
    F/d ratio:

(Focal length)/ (Diameter of the dish): 0.43301
    Profile of the parabola:
        $X^2 = 4.598 \ Y$

Table 2.1-Profile of the parabolic dish

X in m	Y in m
0	0
0.1	0.0021748
0.15	0.0048934
0.2	0.0086994
0.25	0.0135928
0.3	0.0195737
0.35	0.0266420
0.4	0.0347977
0.45	0.0440408
0.5	0.0543714
0.55	0.065789
0.6	0.078295
0.65	0.091887
0.7	0.106568
0.75	0.122335
0.8	0.139191
0.85	0.157134
0.8920	0.173045

Fig 3.1-Solar Parabolic Dish with receiver plate

2.2. Reflectors for the Concentrators:
    Plane Mirror   : Back side silver coated plane mirror
    Thickness of the reflectors : 1.5 mm
    Size of the reflector (L1)   : 7.5 cm x 7.5 cm
    Reflectivity   : 0.95
    α'   : $\omega_O + \Delta\omega_O$
    Where, ω_O : 0.2667o

$\Delta\omega_O$: 2.08590

2.3 Design of Solar Receiver

Diameter of the receiver, $D_1 = \dfrac{4*f*\tan(\omega_o + \Delta\omega_o)}{(1+\cos\varphi)*\cos\varphi}$

$$D_1 = \frac{4*0.77254*\tan(0.2667+2.0859)}{(1+\cos 60^o)*\cos 60^o}$$

D_1 = 0.16927 m or 16.927 cm

2.4 Actual Concentration Ratio:

$$CR = \frac{A_P}{A_R}$$

$$CR = \frac{2.5}{\Pi * 0.084635^2} = \mathbf{111.0938}$$

2.5 Complete specification of the Solar Parabolic Dish Collector:

Aperture area of the dish   : 2.5 m^2

Diameter of the dish   : 1.7841 m

Rim angle of the dish   : 60°

Focal length of the dish   : 0.77254 m

Ideal error   : 4.655 m rad (0.2667^o)

Ideal solar image width   : 0.01917 m

ProfileGeometry   : $X^2 = 4*(0.2575 + 0.8920)\,Y$

$X^2 = 4.598\ Y$

Reflector   : Back side silver coated plane mirror

Reflectivity   : 0.95

Thickness   : 1.5 mm

Facet size   : 0.075 m x 0.075 m

Actual concentration ratio : 111.0938

Slope error in the dish   : 22.155 mrad ($0.2667^o + 1.042713^o$)

III.   NANO-COOLING ARRANGEMENT FOR CPV s

The Solar power plants with surface receivers have low overall energy conversion efficiencies due to large emissive losses at high temperatures. Alternatively, volumetric receivers promise increased performance because solar radiation can be transferred into a fluid medium, which subsequently reduces the concentrated heat at the surface. Nano fluid-based direct solar receivers, where nano particles in a liquid medium can scatter and absorb solar radiation to efficiently distribute and store the thermal energy.

Suspended nano-particles in conventional fluids, called nano-fluids, have been the subject of intensive study worldwide since pioneering researchers recently discovered the anomalous thermal behaviour of these fluids. The enhanced thermal conductivity of these fluids with small-particle concentration was surprising and could not be explained by existing theories. Nano-fluids have intensified thermo physical properties such as viscosity, thermal diffusivity, thermal conductivity, and convective heat transfer coefficients compared to conventional fluids. A new and simple way to improve performance of solar collectors is to use nano-fluid in place of conventional heat transfer fluid

3.1 Development of nano-fluid receiver box:

The test apparatus was built with aluminium that measures with a copper channel of 6mm diameter and length of 1500 mm. This channel is made as coil (figure) and inserted into the test apparatus for the water flow as shown in figure 4.1. The apparatus is connected to an inlet and outlet channel made of PU hose through which water flows to the copper channel.

Three different groups of nanofluids, with water as the base fluid, were considered: Al_2O_3 with the concentration of 1M, Al_2O_3 with the concentration of 0.5M, Al_2O_3 with the concentration of 0.1M.

Fig.3.1.Copper tube for water flow

Fig.3.2.Nano-fluid receiver box with copper tube

3.2 Piping Connections of Receiver box:

Fig.3.3.Nanofluid Receiver with inlet and outlet

Fig.3.4.Receiver with knob for nanofluid

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IV.   COST ANALYSING (CONCLUSION)

Using a solar panel for generating the electricity is costlier than the CPV cell. Even for generating more power, more panels has to be inserted according the requirement and needs more space and also cooling arrangement cost also increases as panel increase . But in CPV cell cooling cost of one cell is same as that of many cell and it also acquire less space and the power equal to the solar panel.

EQUIPMENTS	QUANTITY	PRICE
Solar cell	1	3375
Parabolic dish	1	3000
Solar power meter	1	7100
reflectors	(75*75)cm	4000
Nano fluids fabrication	-	800

possible section may be presented after the conclusion, if desired.

presented two papers in national conference. His research areas of interest are Distributed Generation.

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