Analytical Analysis for Receiver and Its Processing for A 30 Kw CL-CSP System at RGPV Bhopal

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Abstract— A solar project named cross-linear concentrated solar plant for heating and refrigeration system has been designed and implemented behind the boy's hostel building at UIT RGPV Bhopal. The CL-CSP system is formed by sixty heliostats, rectangular collectors is mounted on a base pillar structure with vertical axis, allowing solar tracking in the Sun azimuthally plane, with the aim of maximizing radiation over the tilted surface of rectangular board that have mirror facets over it . The receiver structure has combination of both line focusing and point focusing principle. These sixty heliostat's control and instrumentation has been done so that mirror board could fully concentrate on four receiver line placed above the heliostats. The main aim of this paper work is to make a performance analysis of CL-CSP receiver system by using air as a heat transfer fluid and capture a high range of temperature approximate 600C air temperature.

Key words: CL-CSP system, heliostats, cross-linear

I. INTRODUCTION

The utility electricity sector in India had an installed capacity of 298 GW as of 31 March 2016. Renewable Power plants constituted 28% of total installed capacity and Non-Renewable Power Plants constituted the remaining 72%. The gross electricity generated by utilities is 1,106 TWh (1,106,000 GWh) and 166 TWh by captive power plants during the 2014–15 fiscal. The gross electricity generation includes auxiliary power consumption of power generation plants. India became the world's third largest producer of electricity in the year 2013 with 4.8% global share in electricity generation Surpassing Japan and Russia. During the year 2014-15, the per capita electricity generation in India was 1,010 kWh with total electricity consumption (utilities and non utilities) of 938.823 billion or 746 kWh per capita electricity consumption. Electric energy consumption in agriculture was recorded highest (18.45%) in 2014-15 among all countries. The per capita electricity consumption is lower compared to many countries despite cheaper electricity tariff in India. By the end of calendar year 2015, despite poor hydro electricity generation, India has become power surplus country with huge power generation capacity idling for want of electricity demand. The calendar year 2016 started with steep fall in the international price of energy commodities such as coal, diesel oil, naphtha, bunker fuel and LNG which are used in electricity generation in

India.

As per the present estimates, India has an estimated renewable energy potential of approx 895 GW from commercially credulous sources with 750 GW solar power potential pretentious only 3% wasteland is made available [6]. Emphasizing the need to generate more electricity from clean energy sources, the government today announced a gigantic renewable power production goal of 1, 75,000 mw in the next seven years. Of the total 1,75,000 mw planned to be tapped by 2022, solar power will have a huge share of 1,00,000 mw followed by 60,000 mw from wind energy, 10,000 mw biomass energy and 5,000 mw of small hydro projects.[7]

II. SOLAR RECEIVER

A. *Introduction:*

The receiver operation is very simple since it acts as a heat exchanger. The goal of the receiver is to convert the solar radiation into thermal energy to obtain as high temperatures as possible, ranging from 800 oC to 1000 oC with the lowest pressure drop possible. It is not that effortless to achieve such high temperatures. For this reason, volumetric receivers have been designed, which can be either pressurized or atmospheric. There exist a wide variety of solar receivers according to the type of working fluid used, the power required and other aspects to consider. But the development of pressurized air receivers is closely related to the use of hybrid plants, where solar energy reduces the fuel consumption.

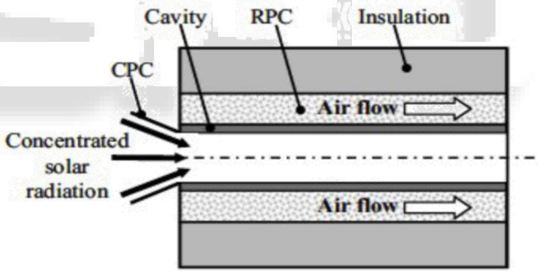


Fig. 1: Solar receiver concept

III. SOLAR THERMAL ENERGY

There are two ways to extract electricity from solar radiation; Photovoltaic and CSP. The previous refers to the direct conversion of sunlight to electricity whereas the latter for the use of heat to produce electricity. In distinction to photovoltaic, CSP technologies do not produce electricity directly through solar radiation, but use concentrated solar energy to indirectly produce heat and power. CSP is a capable technology for power as no fossil fuel is utilize in this technology. Therefore, no greenhouse gases are emitted. This is important features of most solar thermal technologies.

A. *Focusing System for CSP Technologies:*

The goal of Concentrating Solar Power resides in exploiting the solar energy through the conversion of the solar radiation in thermal energy. The thermal energy can be used as it is or as a heat source of a thermodynamic cycle to produce electric energy. The possibility of implementing a thermal energy storage can represents an advantage over other renewable energy sources (i.e. Photovoltaic, wind etc.) whereas the hybridization of the two solar thermal technologies to make innovative CSP system represents a promising concept to increase the market penetration of concentrating solar energy technology . As regards the classification of the concentrating solutions, a first approach divides the technology depending on the kind of the absorber geometry in line-focus such as parabolic troughs and linear Fresnel reflectors, and point-focus category, such as solar towers and parabolic dishes. It is important to underline that the parabolic trough technology covers more than the 90% of the total number of CSP plants. Let us briefly understand the concept of line and point focusing.

1) Linear Focus Systems:

The linear focus systems implement parabolic mirrors (e.g. parabolic trough) or segmented mirrors (e.g. linear Fresnel reflectors) which concentrate solar radiation on a tubular receiver in which a heat transfer fluid or directly the working fluid (i.e. water for direct steam production) circulates. Due to the different absorber geometry, the tracking system is simpler than the point-focus one; in particular, the linear focus systems implement a single axis tracking.

2) Point-Focus Systems:

The basis of this concept resides in a two axis tracking system that allows the solar energy to be concentrated on an ideal point receiver. The main advantage of the point focus systems can be identified in a higher concentration ratio (compared to linear focus systems) that leads to higher operating temperatures. The concentration ratio is of the order of thousands of suns with maximum reachable temperature that could be higher than 1200 °C. As a general consideration, the above mentioned advantage has to face the high investment costs that are necessary to build a system able to concentrate high power flux on an ideal single point.

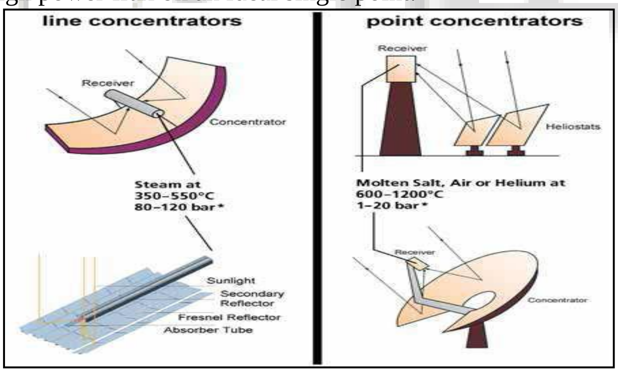


Fig. 2:

IV. CSP TECHNOLOGY AND COMPARISON

Solar thermal technology basically converts sunlight directly into heat and makes this heat available for different applications. The main solar thermal application is domestic hot water heating (DHW) for residential homes, since the temperature level required is moderate (45°C to 60°C) and DHW is required during all over the year. Space heating systems and process heat applications for little temperature up to 95°C, as well as for medium temperatures up to 250°C or very high temperature up to 400°C are later developments. Solar thermal systems vary according to collector type and escalating, storage volume, control policy and system configuration to provide the heat required with the right temperature and the right volume at the lowest investment costs. Therefore, solar thermal systems must be pliable to suit different types of application, taking into account a great number of factors [12].

Technolog y	Temperatu re	Operatio n	Cost ($/Kw)	Efficienc y
Parabolic Trough	400ºC	Possible	4,156	10-15%
Solar Tower	1000ºC	Possible	4,500	14-17%
Parabolic Dish	750ºC	Still in R&D phase	6,000	18-25%
Linear Fresnel	270ºC	Possible	2,200	9-15%

Source: A Review of Concentrating Solar Power (CSP) In
Malaysian Environment, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3, Issue-2, December 2013

V. BASIC OVERVIEW OF CL-CSP SYSTEM

A. Introduction:

CL-CSP system is the amalgamation of two solar thermal technologies. When low construction cost of linear Fresnel LF and high concentration (high efficiency) of central tower is hybridized on a specific platform along with proper management of different parameters, a new system known to be CL-CSP system is formed. The basic concept of CL-CSP system is as follow.

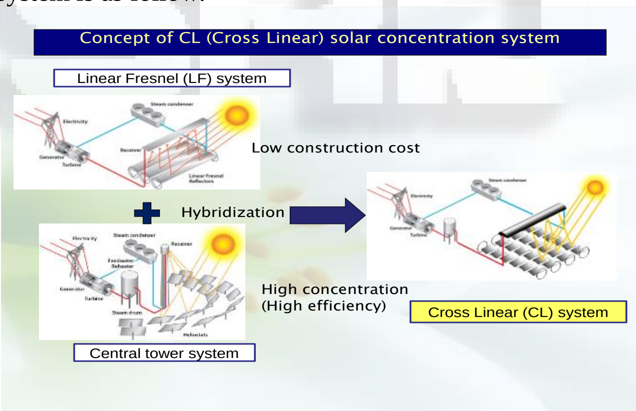


Fig. 5: concept of CL(cross linear) solar concentration system[17] Source: http://www.slideserve.com/zoe-noble/solar-thermal-technology-in-india-issues-and-opportunities

The above analysis shows that how a working model has been formed by hybridizing linear Fresnel and central tower system. The concept of low construction cost and high concentration (high efficiency) from linear Fresnel and central tower is utilized in making of cross linear system.

In the given figure, this is pointed out that how a mirror line (N-S) and receiver line (E-W) have been linked that manages to hold high temperature in CL-CSP system

Figure 6 shows the drawing of the CL system which consists of linear mirror lines and receiver lines. The both lines are cut each other at right angles; the mirror lines are associated on a north-south axis, and the receiver lines, on an east-west axis. In Fig. , the mirrors are placed in a mirror line set up in North-South direction, and can be rotated along the mirror line axis. Every mirror situates at the center of the horizontal line and celestial sphere. All the incidents are in the same way for each mirror, therefore apparently we may say that we could concentrate the sun light with these mirrors by using a unusual elevation angles for each mirror at a nearly the same rotation angle. That means, we have to control the rotation angle for each mirror, because the rotation angles are different for each mirror placed, but a number of mirrors located at some distance from receiver can be rotated together within a required error sort; we can function several mirrors within some error range by adaptation of the same rotation angle for every mirrors. Thus, we can track the sun and make a solar concentration by adjusting the rotation angle of the north-south axis and elevation angle.[18]

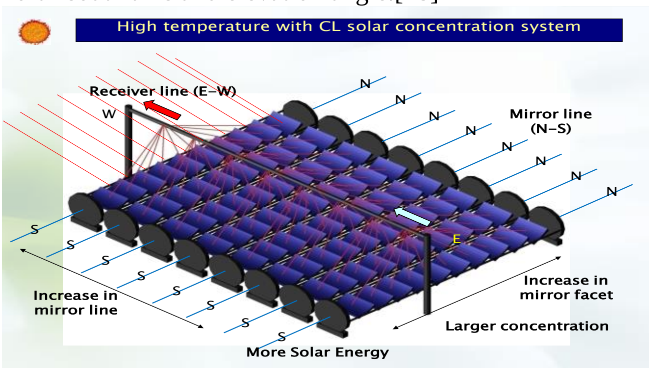


Fig. 6: mirror and receiver line in CL-CSP system[17]
Source http://www.slideserve.com/zoe-noble/solar-thermal-technology-in-india- issues-and-opportunities.

VI. MECHANICAL VIEW OF THE SOLAR RECEIVER SYSTEM

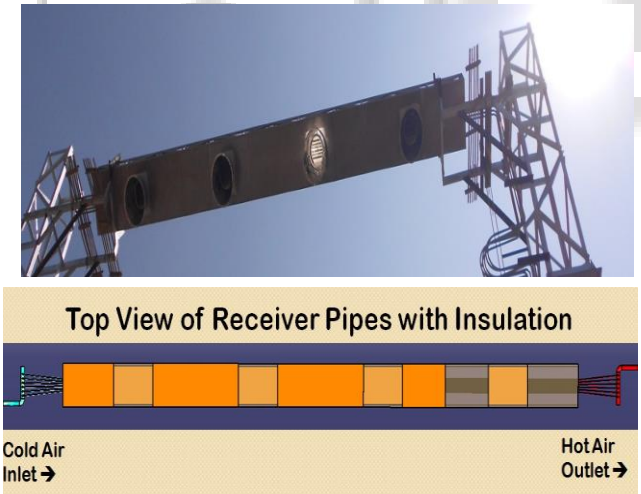


Fig. 7: Mechanical View of the Solar Receiver System

VII. METHODOLOGY OF PROJECT

A. *Introduction:*

This chapter explains detail about the methodology of the whole system and flow of step that used in "Solar Receiver System". This chapter also describes further more about the planning of the whole project that is included about software and hardware development. The CL-CSP system has been utilized cavity type receiver. There are four different points of focus in this receiver. Each line of Heliostat will focus on single point of receiver; it means the focus point of 15 Heliostat is same. On this way the conversion of point focus to line focus takes place. There are 4 lines i.e. A, B, C and D. Each line is having 15 Heliostat for example in A line starting from A1 to A15 total 15 Heliostat. Same as B, C and D line. Heat Transfer fluid i.e. Air will pass at the input through pipes inside the receiver and at each points of focus it will get heat and then at the output it will become 600 degree Celsius. There are six tubes inside the receiver and in every tubes temperature sensors are installed, so there are two temperature shows at SCADA output first is skin temperature and second is the air temperature.

Design Theory

The design theory has been divided into two parts

1) Heat exchanger design
2) Receiver structure design

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single- or multi component fluid streams.

In a few heat exchangers, the fluids exchanging heat are in direct contact. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak.

Introduction for Double pipe heat Exchanger

A double pipe heat exchanger, in its simplest form is just one pipe inside another larger pipe. One fluid flows through the inside pipe and the other flows through the annulus between the two pipes. The wall of the inner pipe is the heat transfer surface. The pipes are usually doubled back multiple times as shown in the diagram at the left, in order to make the overall unit more compact.

The term 'hairpin heat exchanger' is also used for a heat exchanger of the configuration in the diagram. A hairpin heat exchanger may have only one inside pipe, or it may have multiple inside tubes, but it will always have the doubling back feature shown

In double pipe heat exchanger design, an important factor is the type of flow pattern in the heat exchanger. A double pipe heat exchanger will typically be either counter-flow or parallel flow. Cross-flow just doesn't work for a double pipe heat exchanger. The flow pattern and the required heat exchange duty allow calculation of the log mean temperature difference. That together with an estimated overall heat transfer coefficient allows calculation of the required heat transfer surface area. Then pipe sizes, pipe lengths and number of bends can be determined.

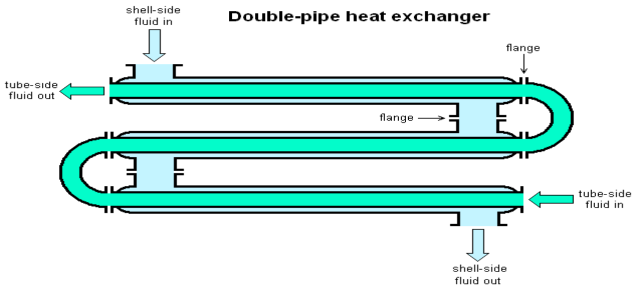


Fig. 8:

B. Counter Flow and Parallel Flow in A Double Pipe Heat ExchangerL:

A primary advantage of a hairpin or double pipe heat exchanger is that it can be operated in a true counter flow pattern, which is the most efficient flow pattern. That is, it will give the highest overall heat transfer coefficient for the double pipe heat exchanger design.

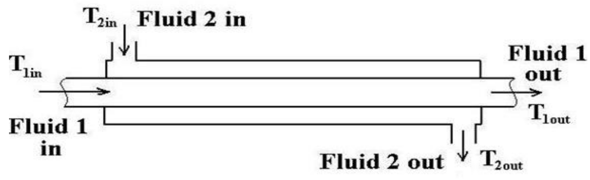


Fig. 9: Double Pipe Heat Exchanger Parallel Flow

Also, hairpin / double pipe heat exchangers can handle high pressures and temperatures well. When they are operating in true counter flow, they can operate with a temperature cross, that is, where the cold side outlet temperature is higher than the hot side outlet temperature.

C. Receiver:

The receiver exit temperature is one of the most important aspects regarding this project.

Fig. 10: Diagram: View Of The Receiver

Equipments	Air Receiver tubes
Operating pressure	514kpas G
Operating temperature	Inlet 300 and outlet 600 deg C(metal max 840 deg C)
Design pressure	780kpas G
Design temperature	750deg C (metal 950deg C)
Tube length	13200 mm
No of tubes	6 Nos
Tube material	Alloy 800H
Empty weight	1250kg approx
Inlet header pipe	
Pipe size	88.9mm – OD Thick-3.05 mm
Pipe length	1530 mm
Pipe material	Alloy 800H seamless
Inlet header pipe	
Pipe size	88.9mm – OD Thick-3.05 mm
Pipe length	1530 mm
Pipe material	Alloy 800H seamless

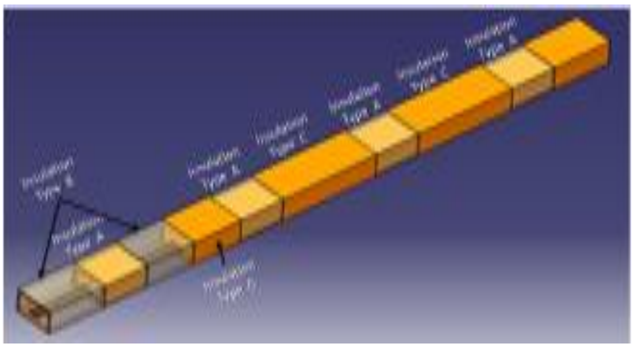
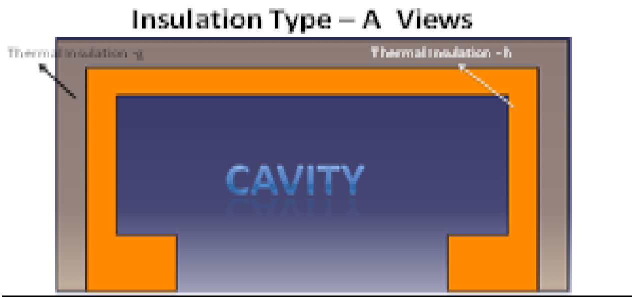


Fig. 11: Insulation Pattern in Receiver



Parts	Symbol	Type or Grade	Materials & Spec.
Thermal insulation Of Cavity	g	Rock Wool Board	50mm t 0.14 W/(m.K) at 600 °C Service
	h	Ceramics Fiber Board	50mm t 0.12 W/(m.K) at 1260 °C Service

Fig. 12: Insulation Type – A Views

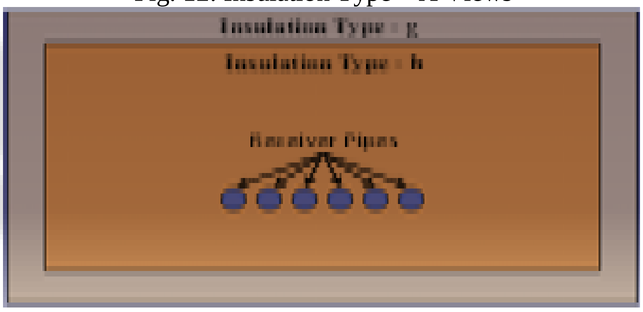


Fig. 13: Insulation Type – Bvalues

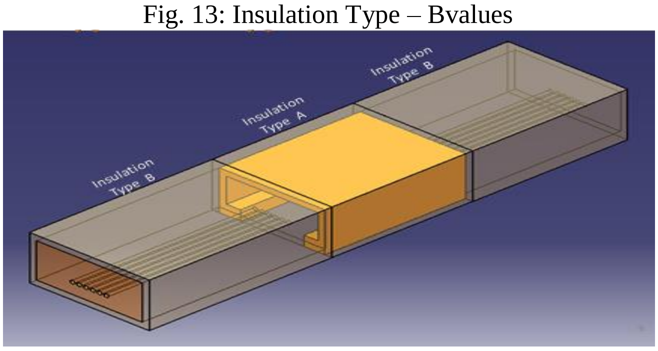


Fig. 14: Type A&B Insulation

Flow rate	334kg/hr
Orientation	Tilt in a angle
Height	16 meter
Span	13.2mm

Table 2:

D. Working Procedure:

1) Sun light falls on the heliostat boards that have facets over it.
2) As the reflectivity of the facets is very highly that helps in making very high intense point on receiver point.

3) As we increase the concentration of heliostat on receiver point from A1 to A15 in a very frequent manner the receiving line gets more intense reflecting sun light at receiver point thereby increasing the temperature.
4) Similar procedure has been followed for B1 to B15, C1 to C15 and D1 toD15 lines as it has high reflectivity gets on the receiver target B, C and D Receiver point.
5) It has been analyzed that the inlet end of the receiver highly compressed air (300Deg C) out from the air electrical heater passes from 6 Nos. tubes go to each receiver point like A,B,C and D, then outlet end of the receiver get 600Deg C air temperature.
6) During this process I have observe the each tubes inside air temperature at the inlet and outlet temperature condition. Like when air passes inside the tubes from D receiver point, I have observe the temperature before passing the D receiver point and after passing the D receiver point, using the temperature sensor.
7) Same procedure follows the A, B and C receiver point.
8) After getting the 600 Deg C air temperatures, air passes the air heat exchanger, in this heat exchanger low air temperature passes from air pre heater and another high temperature air heat exchange from each other.
9) After passes the heat exchanger air goes to the steam generator then becomes steam.
10) Before getting a steam another cycle works like water flows from the economizer at the one end and another end highly temperature air passes, water takes heat from the air then goes to the steam generator, then becomes saturated steam and its steam goes to the super heater then becomes super heated steam.

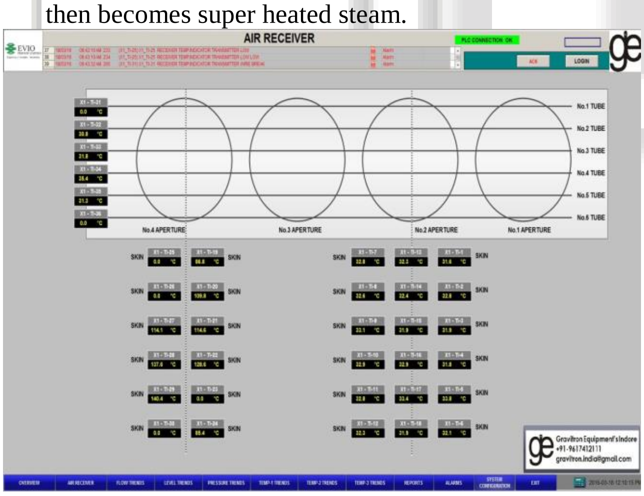


Fig. 15:

VIII. COMPARISON OF CSP TECHNOLOGY WRT CL- CSP SYSTEM

Concentrating solar power (CSP), also referred to as concentrating solar thermal power, represents a dominant, clean, continual, and trustworthy source of energy with the capacity to entirely satisfy the present and future electricity needs of the India. Concentrating solar power plants produce no carbon dioxide (CO2), thus reducing carbon emissions from electricity production by approximately 600 pounds per megawatt-hour. The new system based on CSP system is CL-CSP system having hybridization of solar thermal technology that plays a significant role in removing the limitation of previous solar thermal technologies.

	Cross linear	Tower , trough, linear Fresnel
Temperature	300-600 deg c	Tower:600 deg c Trough:400 deg c LF :300-900 deg c
Concentration	100-1000	Tower:300-1000 Trough,LF<100
Thermal fluid	Liquid,water,oil,gas, steam, co2	Tower: molten salt, steam Trough:oil,steam,molten salt LF: steam
CL heliostat	Axis:1.01	Tower:2.0/high precision Trough,LF:1.0/medium precision
CL receiver	Cavity, CPC, pipes	Tower: cavity Trough:vacuum pipe LF:pipe,CPC,cavity

Source:http://www.slideserve.com/zoe-noble/solar-thermal-technology-in-India-issues-and-opportunities

To solve these problems on the efficiency drawback, a new solar concentration system, CL system, has been invented. This dissertation will describe the optical principles of CL system and synthesizes the enhanced efficiency by some factor. For a practical development of the CL system, we have started the construction of 30kW pilot plant in India at RGTU Bhopal . This paper includes an optical examination on the joint collaboration between Japanese and Indian companies, institutes and universities, which has been launched to build solar plant based on CL solar concentration technology. In addition we have slightly examined to find out another application of the CL system for CPV, because the CL system has a inimitable characteristic on the coma tic aberration; it is very small during 9am to 3pm during the day time [17].

IX. ADVANTAGE OF THE CROSS LINEAR SYSTEM

In the CL-system, we can placed a Number of mirrors in one mirror line, and select any heliostat number. This enforced us to take a broad range in the concentration degree from lower one of 50 to higher one of 300-500. Therefore, we can get a wide temperature range from 200 to 550C of the thermal fluids of air, steam and molten salt. When we apply a superior concentration degree, we can reduce the numbers and length of the receiver lines, which gives an advantage for lower the outlay cost and power generation cost compared to trough and Linear Fresnel systems. Another interesting benefit is that with the CL-system, a advanced sun light collection efficiency can be obtained at higher latitudes wrt to the existing conventional concentration systems.

One of our simulation results Shows that the amount of collected solar energy by CL-scheme is about 2 times larger than that obtained by trough system in winter season, we can get the equal amount of collected solar energy during 10-14 hour in daytime and in winter season as that of in summer season. For our CL-system, we can use a one way-curled mirror which can be more willingly mass produced with a high accuracy. CL-system also requires less weighty steel material, and On-site installation can be achieved for a faster construction.

X. Conclusion

From the analytical study of CL-CSP system we conclude that the hybridization of solar thermal's two technologies improves the optical as well as collection efficiency. The efficiency of existing solar concentration systems such as Trough and Linear Fresnel are too low in winter season. And, the cosine factor of CL-system becomes higher at the higher latitude. Thus, CL system is suitable for collecting solar energy at high latitudes. On differentiating between CL-CSP and Trough systems, the CL system can collect the maximum amount of solar energy even in winter seasons by keeping the cosine factor at a high level. Conversely, for Trough system, the collected solar energy value drops largely compared to the CL-system in winter season, which is caused by decline in cosine factor and the sunlight duration in winter season. CL-system can provide a wide range in the concentration degree from lesser one of 50 to higher one of 300-500, And that in the temperature of 200-55o 0C.

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