30kW Cross Linear Solar Concentration Pilot Project at RGTU Bhopal

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Abstract— A New revolutionary system for producing unconventional energy in near future is Cross Linear (CL) system has been newly researched and manipulated by Indo-Japan team. The contemporary facts available with respect to conventional sources of energy, it become mandatory for taking some game changing steps in the field of renewable energy sector specially in solar energy. The energy crisis is always a big problem that the world's is facing today. Governments and concerned authority are working to make the use of renewable resources a precedence. As far as in renewable energy is concerned, solar is a dynamic field to approach CSP technology. Now this is the time to configure the CSP system by stabilizing some new technique. The CL-CSP project is one of game changing step in solar energy production. This paper is the analysis of how CL system can get rid of the end loss and increase the optical efficiency compared to Trough and LFR (Linear Fresnel Reflector system) and solar tower. This analysis is to solve the problems in the concentration systems and the lower concentration efficiency of Trough and LFR in the winter season; including a higher temperature around 550-600 °C can be obtained with the CL system.

Key words: Cross Linear, Renewable, CSP

I. INTRODUCTION

Energy sources will cooperate an important role in the world's future given that the global requirement for energy is swiftly rising. Estimates of the world primary energy expenditure are that 80% of the supply is provided by fossil fuels [1]. In view of various statistic, the primary energy use is estimated to rise between 32 and 84% by 2050 as compared to 2011 [2]. However, the fossil fuel assets are rapidly depleting and there is an increasing essential to substantially reduce greenhouse gases and supplementary pollutants in light of the serious climate crisis that will have to be faced unless developing countries control carbon emissions from their power sector in the in the vicinity of future [3]. The effective electricity sector in India had an installed power capacity of 284.303 GW as of 31 December 2015. 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. India became the world's third hieghest producer of electricity in the year 2013 with 4.8% global share in electricity generation surpassing Japan and Russia [4]. For the period of the year 2014-15, the per capita electricity production in India was 1,010 kWh with total electricity utilization (utilities and non utilities) of 938.823 billion or 746 kWh per capita electricity consumption. Electric energy utilization in agriculture was recorded highest (18.45%) in 2014-15 among all countries [5]. India is now the eleventh largest financial system in the world, fourth in terms of purchasing power. It is poised to make marvelous economic strides over the next ten years, with considerable development already in the planning stages. This testimony gives an overview of the renewable energies market in India.

India is already the world's fifth highest producer of wind power. Other renewable energy sources like solar, small hydro, biomass power and bio-fuels are also being gradually more tapped. 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 ENERGY

Various countries all over the world including India are now focusing more on green technology and renewable energy. According to the 2011 projection by International Energy Agency, renewable energy like solar power producer may produce most of the world's electricity within 50 years, enormously reducing the emission of greenhouse gases that damage the environment. There is a high impending for solar energy in India, given that both technology routes for renovation of solar radiation into heat and electricity, namely, solar thermal and solar PV being feasible to be harnessed providing huge scalability [8]. According to Ministry of New and Renew able Energy (MNRE) , the highest annual global radiation is acknowledged in Rajasthan and northern Gujarat. The solar reserve data and maps developed for Northwestern India illustrate the potential for widespread application of flat-plate and concentrating solar collectors across this area. The state of Rajasthan receives about 5.5–6.8 kWh of solar radiation per sq. m per day. It is estimated that almost 35– 50 MW capacity solar power plant can be establish on one sq. kilometer land area according to a recent press release from MNRE.[9]

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.

Ministry of New & Renewable Energy			
Programmed/ Scheme wise Physical Progress in 2015-16 (Up to the month of November, 2015)			
Sector	FY- 2015-16		Cumulative Achievements
	Target	Achievement	(as on 30.11.2015)
GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind Power	2400.00	1315.71	24759.32
Solar Power	1400.00	922,61	4684.74
Small Hydro Power	250.00	106.55	4161.90
Bio-Power (Biomass & Gasification and Bagasse Cogeneration)	400.00	132.00	4550.55
Waste to Power	10.00	12.00	127.08
Total	4460.00	2311.88	38283.59
OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW_{EQ})			
Waste to Energy	10.00	0.50	146.51
Biomass(non-bagasse) Cogeneration	60.00	10.50	602.37
Biomass Gasifiers	2.00	0.20	18.15
-Rural	6.00	8.67	160.72
Aero-Genrators/Hybrid systems	0.50	0.13	2.67
SPV Systems	50.00	46.50	280.85
Water mills/micro hydel	2.00	0.00	17.21
Total	130.50	66.50	1228.48
OTHER RENEWABLE ENERGY SYSTEMS			
Family Biogas Plants (numbers in lakh)	1.10	0.22	48.34
Solar Water Heating - Coll. Areas(million m2)	-	0.00	8.90

Fig. 1: Ministry of New & Renewable Energy
Source: Ministry of New & Renewable Energy http://mnre.gov.in/mission-and-vision 2/achievements/

III. JNNSM TARGETS

A. *Mission Objectives*

The aim of the Jawaharlal Nehru National Solar Mission is to set up India as a global leader in solar energy, by creating the policy provisions for its large scale diffusion across the country as promptly as possible. The Mission adopted a 3-phase approach, straddling the period of the 11th Plan and first year of the 12th Plan (up to 2012-13) as Phase 1, the left over 4 years of the 12th Plan (2013-17) as Phase 2 and the 13th Plan (2017-22) as Phase 3. At the end of every plan, and midterm during the 12th and 13th Plans, there will be an assessment of progress, review of capacity and targets for consequent phases, based on emerging cost and technology trends, both household and global. The aim would be to protect Government from subsidy revelation in case expected cost reduction does not materialize or is more rapid than expected. The instantaneous aim of the Mission was to focus on setting up an enabling environment for solar technology dissemination in the country both at a central and decentralized level. The first phase (up to 2013) focused on capturing of the low execution options in solar; on promoting off-grid systems to serve populations without access to viable energy and reserved capacity addition in grid-based systems. In the second phase, after taking into account the understanding of the initial years, capacity will be aggressively ramped up to create conditions for up scaled and competitive solar energy penetration in the country.[10]

B. *Latest Development*

The Union Cabinet chaired by the Prime Minister, Shri Narendra Modi, gave its endorsement for stepping up of India's solar power capacity target under the Jawaharlal Nehru National Solar Mission (JNNSM) by fivefold, reaching 1, 00,000 MW by 2022. The target will primarily consist of 40 GW Rooftop and 60 GW by Large and Medium Scale Grid Connected Solar Power Projects. With this determined target, India will become one of the biggest Green Energy producer in the world, surpassing several developed countries. The total outlay in setting up 100 GW will be around Rs. 6, 00,000 cr. In the first phase, the Government of India is on condition that Rs. 15,050 crore as capital subsidy to promote solar capacity addition in the country. This capital financial support will be provided for Rooftop Solar projects in various cities and towns, for Viability Gap Funding (VGF) based projects to be developed by the Solar Energy Corporation of India (SECI) and for decentralized generation with small solar projects. The Ministry of New and Renewable Energy (MNRE) intends to achieve the target of 1, 00,000 MW with targets under the three schemes of 19,200 MW. [11]

IV. CONCENTRATING SOLAR POWER (CSP) TECHNOLOGY

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].

Technology	Temperature	Operation	Cost ($/Kw)	Efficiency
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%

Table 2: A Review of Concentrating Solar Power (CSP)

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

Concentrating Solar Thermal technologies (CSP) is used to generate heat or electricity. CSP application use lenses or mirrors and tracking systems to focus a big area of sunlight into a small beam. The concentrated light is then used as heat or as a heat source for a conventional power plant. A concentrating collector system can have a immobile collector or tracking one to track the sun. In stationary systems, the reflector and absorber are in fixed position, usually oriented directly to true south. Tracking devices shift the position of the reflector and the receiver to maximize the amount of sunlight concentrated on to the receiver [13].

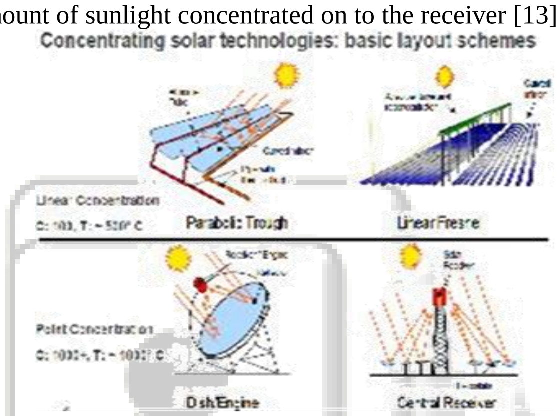

Fig. 1: layout schemes of concentrating solar technologies

A. Parabolic Trough

A parabolic trough has a linear parabolic reflector that concentrates light onto a receiver placed along the reflector's focal line. The receiver is a pipe positioned right above the center of the parabolic mirror and is packed with a working fluid (e.g. molten salt). The reflector follows the sun during the day time hours by tracking along a single axis. The operational fluid is heated to 150-350°C as it flows through the receiver, and is then used as a heat supply for a power generation system. Trough systems are the main developed CSP technology.

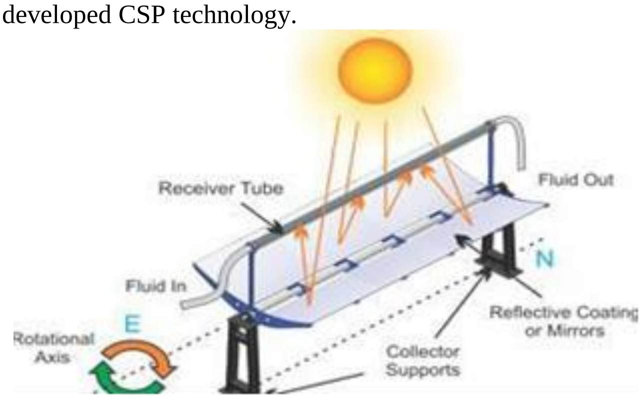

Fig. 2: Schematics of parabolic trough [16]

1) Limitation

The main risk for parabolic trough solar plants to reach market acceptance is the incentives that will allow the plant to be aggressive with current non-renewable cost of generating power. The technology is still relatively new on the commercial market, and there are disadvantages to solar thermal power generation that have delayed its growth. Primarily, the efficiency of these plants is relatively low compared to that of traditional fossil fuel plants, and their equipment and maintenance costs are higher due to the complexity and vulnerability of the technology.

B. Concentrating Linear Fresnel Reflectors

Concentrating Linear Fresnel Reflectors are CSP plants which use many thin mirror arrays instead of parabolic mirrors to concentrate sunlight into two tubes with working fluid. The benefit is that flat mirrors are cheaper than parabolic mirrors. Space utilization can also be better in these. Figure below depicts the Concentrating Linear Fresnel Reflector System.

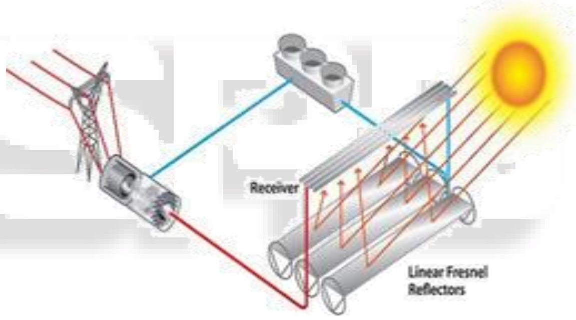

Fig. 3: Concentrating Linear Fresnel Reflectors [16]

1) Limitation

The efficiency disadvantage of Fresnel power plants over parabolic power plants is principally caused by optical losses. The Fresnel collector does not follow the Sun, as it is the case with parabolic troughs. Fresnel collectors do not have only longitudinal cosine losses, but they are affected also by transversal cosine losses. Parabolic troughs, on the contrary, have only longitudinal cosine losses. The problem is that the receiver is fixed and in the sunrise and afternoon cosine losses are soaring compared to PTC. Despite these drawbacks, the relative simplicity of the LFC arrangement means that it may be cheaper to construct and install than PTC CSP plants. However, it remains to be seen if costs per kWh are lower. [15].

C. Solar Power Tower

A spherical array of heliostats concentrates sunlight on to a central receiver mounted at the top of a tower. The heliostats follow the sun on two axes. The central receiver can accomplish very high concentrations of solar irradiation thus ensuing in extremely high temperature for the operating fluid. A heat-transfer medium in this central receiver absorbs the extremely concentrated radiation reflected by the heliostats and converts it into thermal energy. Spain has several solar tower systems working or under construction, up to 20 MW capacity. A solar power tower consists of an array of double-axis tracking reflectors that concentrate light on a central receiver atop a tower. The receiver contains a fluid deposit, which could include seawater. The working fluid in the receiver is heated to 500-1000°C and then used as a heat supply for a power generation or energy storage system.

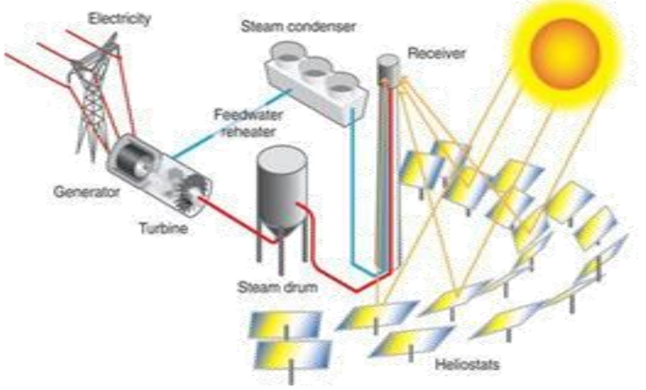

Fig. 4: schematics of solar tower [16]

1) Limitation

The lack of commercial experience means that this is by no means assured and deploying solar towers today includes significant technical and financial risks.

In addition to the major effects of the dimensions of the solar tower, minor losses also play a role in overall tower efficiency. Each component will have allied losses. The collector has many associated minor losses. One important source of loss is the ability of the collector to effectively confine and retain solar energy. The roofing substance is the significant factor for this issue. Due to the greenhouse-like policy, it's desirable to have the material be highly transparent to solar radiation, highly reflective to the heat re-radiated by the ground beneath the collector, and highly insulating. The chimney can also have associated friction losses, but again, the losses associated with the drag in the chimney are minor [16].

V. 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, co_2	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

Table 3: Comparison

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].

VI. BASIC OVERVIEW OF CL-CSP SYSTEM

CL-CSP system is hybridization 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 follows.

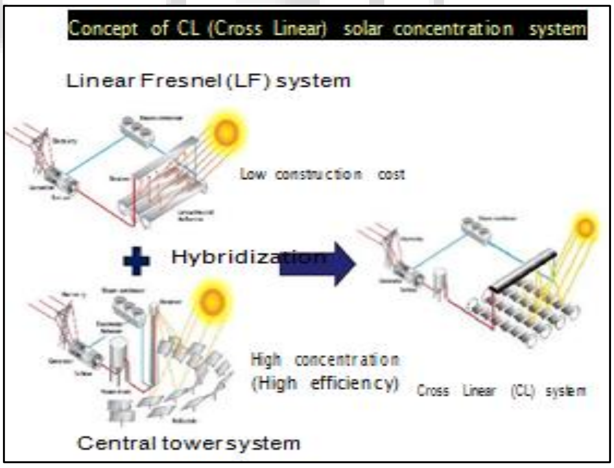

Fig. 5: concept of CL (cross linear) solar concentration system[17]

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]

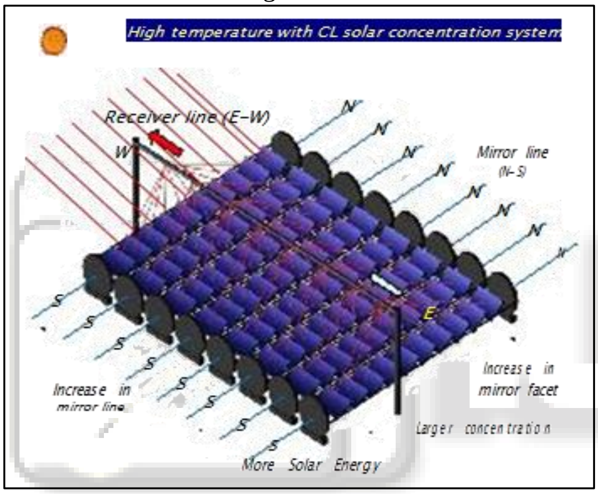

Fig. 6: mirror and receiver line in CL-CSP system[17]
Source http://www.slideserve.com/zoe-noble/solar-thermal-technology-in-india- issues-and-opportunities.

VII. 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.

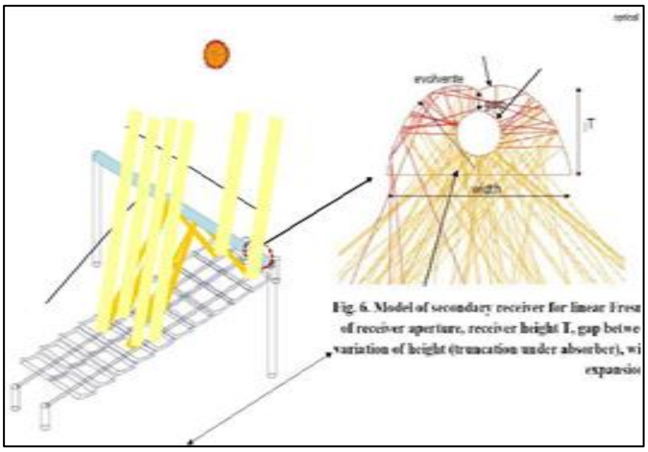

Fig. 7: CL-CSP solar concentration system receiver[171]
Source: http://www.solarflame.co.jp

VIII. 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 200-550^{0}C.

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