Analytical approach for Tracking Control System and its Instrumentation of a 30 KW CL-CSP System at RGPV Bhopal

Mr. Sandeep Patidar[1] Dr. Mukesh Pandey[2] Mr. Anurag Gour[3]
[1]M.Tech. Student [2]Head of Dept. [3]Assistant Professor
[1,2,3]Department of Energy Technology
[1,2,3]UIT RGPV Bhopal

Abstract— A solar-powered 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 . 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. This work describes the control system implemented to achieve accurate solar tracking phenomena. The criteria are to design and implant the control system is to maximize radiation over the tilted surface and thereby at the receiver, and to obtain a reliable and durable structure.

Key words: CL-CSP System, Heliostats, Cross-Linear

I. Introduction

Energy sources will play an important role in the world's future given that the global requirement for energy is swiftly rising. The progressive increase of the global energy demand is a direct consequence of the world economic growth; in particular, in the last twenty year, the steep increase of new economy like China and India has produced an intensification of the energy demand that has to be faced by the whole global system. Taking into account the data of the International Energy Agency ("IEA") more than 80% of the total primary energy derives from fossil fuels.[1] The strong use of fossil fuels with the consequent relevant emissions of CO_2 represents the most important driver of the global warming. In view of various statistics, 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 vicinity of future .[3] 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.[4]

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 [5]. 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.[6] 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 Tracker

A. Introduction

Solar Tracker is a Device which follows the movement of the sun as it rotates from the east to the west every day. The main function of all tracking systems is to provide one or two degrees of freedom in movement. Trackers are used to keep solar collectors/solar panels oriented directly towards the sun as it moves through the sky every day. Using solar trackers increases the amount of solar energy which is received by the solar energy collector and improves the energy output of the heat/electricity which is generated. Solar trackers can increase the output of solar panels by 20-30% which improves the economics of the solar panel project. The main tracking types are described closer in the following chapters.

B. Need for Solar Tracker

The energy contributed by the direct beam drops off with the cosine of the angle between the incoming light and the panel. The sun travels through 360 degrees east-west a day, but from the perspective of any fixed location the visible portion is 180 degrees during a 1/2 day period. Local horizon effects reduce this somewhat, making the effective motion about 150 degrees. A solar panel in a fixed orientation between the dawn and sunset extremes will see a motion of 75 degrees on either side, and thus, according to the table above, will lose 75% of the energy in the morning and evening. Rotating the panels to the east and west can help recapture these losses. A tracker rotating in the east-west direction is known as a single-axis tracker.

The sun also moves through 46 degrees north-south over the period of a year. The same set of panels set at the midpoint between the two local extremes will thus see the sun move 23 degrees on either side, causing losses of 8.3% A tracker that accounts for both the daily and seasonal motions is known as a dual-axis tracker.[8]

III. Solar Themal 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. [9]

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. [10]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.

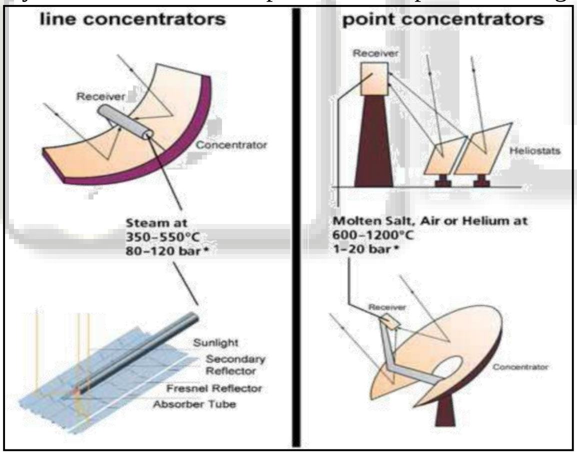

Fig. 1: line and point focusing principles

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.[11]

B. 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].

Technology	**Temperature**	**Operation**	**Cost ($/Kw)**	**Efficiency**
Parabolic Trough	400°C	Possible	4,156	10-15%
Solar Tower	1000°C	Possible	4,500	14-17%
Parabolic Dish	750°C	Still in R&D phase	6,000	18-25%
Linear Fresnel	270°C	Possible	2,200	9-15%

Table 1: CSP technology and comparison
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

IV. BASIC OVERVIEW OF CL-CSP SYSTEM

A. Introduction

Rajiv Gandhi Technical University Bhopal is devoted to the design of supervision and control systems that allow the maximum performance of their renewable energy facilities, which are working recently for a hybrid solar thermal power plant of generation capacity of 30 kW. The objective of this paper is to illustrate the implementation of the supervision and control system for the azimuthally sun tracker of the actuator controlled rotary heliostats platform that supports a field of solar mirror board collectors, thus producing the necessary infrastructures for the study of solar tracking algorithms. This will allow us to obtain the maximum benefit from the installation. Necessary guidelines have been designed, with respect to instrumentation and control, for the attainment of a solar tracking system that fulfills easily certain specifications, so that it will be used as future reference.[13]

Control and supervision of our CL-CSP system is performed for better reception of sun's radiation at the receiver. Each heliostat has their separate control boxes that have points for actuators signaling, power in, and Ethernet cabling, along with the microcontroller kit and their programming operation. The control box wired to actuators for performing the movement operation in both east-west and north-south directions that follow the principles of suns azimuthally plane. This system have been implemented through a distributed control network based on Lon-Works technology, which offers all the advantages of a distributed control system as far as robustness and reliability with low cost in comparison with other solar thermal systems. A number of simulations have been run in Lab View with the objective of quantifying, theoretically, benefits obtained with a tracking system versus a system without tracking, concerning to the irradiance received over the solar collectors.

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.

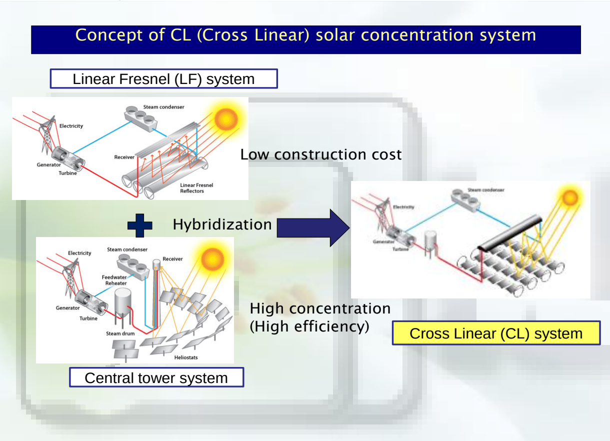

Fig. 5: Concept of CL (cross linear) solar concentration system [17] Source: http://www.slideserve.com/zoe-noble/solar-thermal-technology-in-india-issues-and-opportunities

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]

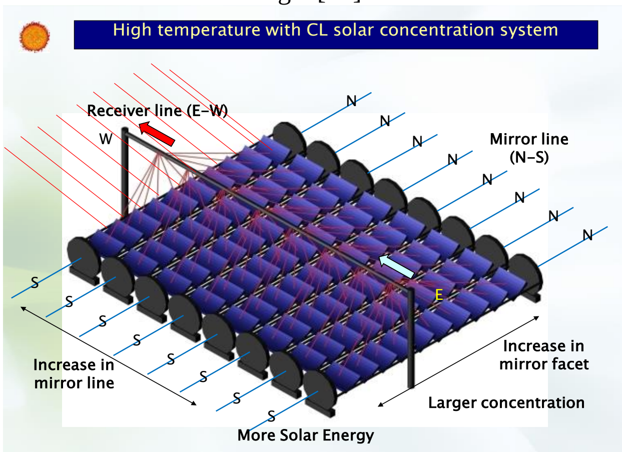

Fig. 6: Mirror and receiver line in CL-CSP system[17] Source http://www.slideserve.com/zoe-noble/solar-thermal-technology-in-india- issues-and-opportunities.

B. Mechanical Description of the Solar Tracking System

Solar tracking system is formed by a horizontal base frame that supports a rectangular board that have four facets over it and it is designed and prepared for concentrating the light on receiver structure placed above the heliostats. The mirror board seems to be plane surface but it is actually making a concave surface indicating square aperture .This board contains four facets over it that have plane surface towards the center thereby focusing the sun's rays on a single target point that is actually our receiver. This platform, through two actuators, generates a slow rotation movement on a both direction in east- west and north-south located below the base plate that is joint to board. It is made in the horizontal plane so that the solar tracking is azimuthally.

Fig. 7: Solar Tracking System

The moving tracking system is a concave surface structure that forms a rectangular dimension of length and width is 174 cm and 143cm respectively for an individual board that has facets which are of 75 cm square rests over board at equidistant points of support. Base plate is a square shape structure made of steel alloy and it supports the board. These 4 points of line support are bearings, two of them have actuators. Each actuator is working on a very minute supply of voltage signaling. These actuators have been wired to control box given below in the figure no. 1 by appropriate micro controller programming the controlling of actuators have been performed in both the direction. This way movement is transmitted to the control box whose output finally screened on control room's computer. The system has two low supply actuators assemblies formed by a 24V single -phase asynchronous motor. This actuator is activated so that the motor is not free, because the canvas-effect produced by the collectors may move the platform causing dangerous efforts in the structure. The system is designed for correct working with both of its actuators. The traction is duplicated to balance the forces in the platform, thus, operation with both actuators is recommended, and working only with one when the other is damaged is not at all preferred. Design velocity of the solar tracking is 8mm/s . Efficiency of these collectors is slightly greater than flat plate collectors, but also its durability is considerably greater. It has been observed that some of the facets are outside the board that's why it has been cut by certain margin for proper establishment of facets over board. The base plate monument is flexible in all of it direction So it has been considered the possibility of incorporating variable speed controllers that move the system smoothly under normal operation.

V. Methodology of Project

A. Introduction

This Para explains detail about the methodology of the whole system and flow of step that used in "Solar Tracking 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 have been utilized dual axis tracking system for movement in both of its axis e.g. EW axis and NS axis. This movement has been performed via actuators placed below the heliostats board. Actuators operation works on the basis of time vs. distance phenomena. Whatever moves we want to give whether it is forward or backward, we can give commend via laptop system and manually adjust the position of actuators so that heliostat can supervise the suns radiation towards the receiver focal point. For investigation purpose we have taken row (A) e.g. from A1 to A15, for taking calibration and analyzing the various parameter adopted for following the suns movement throughout the day and year. We have also investigated the performance of row (A) by recording the air temperature and skin temperature of our CL-CSP system. It is scientifically says by Pro. Yotaka tamura that the CL-CSP system has to give the wide range of temperature approx. 550 to 600 degree Celsius, for almost 300 sunny days. So purpose of this investigation is to analyzing the working system of row (A) by taking its calibration and temperature records via a well developed tracking system.

B. Whole Planning

Whole planning for this project has been divided into two steps and we have full Flowchart of the whole planning for CL-CSP-TRACKING and CL-CSP-TEMPERATURE

1) CL-CSP-Tracking

Tracking is the integral part of our CL-CSP system. An accurate tracking system helps in improving the overall system performance. For this step to conduct we must have already installed electronic setup for controlling laptop system and well developed control and instrumentation work. Next, the project that we get will be discussed with supervisor to get a suitable hardware and software development. Next, the research about the hardware is doing to know what electronic component and assembly programming needed to develop this project. Controlling of these actuators has been performed via laptop system at the site or at control room. The integral parts of our CL-CSP tracking system is

1) Actuators
2) Control box
   - PCB
   - CPU
3) Heliostat conductor software

2) CL-CSP-Temperature

We must have a well-developed C&I system for functional analysis of our CL-CSP system at the site. Automation for the project also plays a significant role in whole project planning. in such a case we are going for PLC–SCADA system at the control room. Finally we can check the performance of temperature reading on computer screen. After focusing full row (A) to the receiver point just above row (A), we can observe continual increment in temperature records. We must have well developed receiver and heat-exchanger setup that works as a intermediary in performing the task of taking temperature records.

Lastly, the software is installed for controlling the movement of actuators for focusing the heliostats.

Flow chart for both the operation

a) For CL-CSP-Tracking system
- Working for CL-CSP project as a M. Tech. Engg. Dissertation
- Discuss with guide about the project and investigate the new ideas
- Taking tracking concept as a research part and investigation
- Assemble the required component for the investigation
- Start the calibration work for CSP, CPV, and fix the alignment data for each heliostats
- Do the required calculation for tracking error , variance and leveling

b) For CL-CSP temperature
- Selecting the heliostats for manually focusing work
- Step by step focusing the heliostat from A1 to A15
- Perform fast operation for stabilizing the sun's rays on target point to increase the air and skin temperature
- Finally discussion on result obtain and analysis work

C. Project Planning

- Sunlight projection on heliostats
- Next target is to make reflected radiation on receiver point which is somewhere else For this we will manually adjust the position of actuators
- Now we have to take following readings via'' Heliostats Conductor Software '' (by manual tracking)
  1) Alignment data

2) CSP data,
3) CPV data

- These readings are nothing but position of actuators length that is utilized for calculation of some tracking parameters by solving non-linear mathematical equation by' Iteration Method'
- When this parameter feed into each heliostats, it start working automatically wrt sun's movement (by auto-tracking)
- This process leads to a stationary point on receiver that built a wide range of temperature and can be seen at computer screen

D. Hardware Requirements:

8051 series Microcontroller, Dummy Solar heliostats, actuators, PCB (Voltage Regulator, Diodes, Relay driver IC, Transformer), CPU (micro-controller)

The aim here is to check whether the equipment available

- Hardware Implementing
- Software Implementing

E. Software Requirements:

Heliostat conductor
Languages: python ()

F. Working of Tracking System

This project has two ways of tracking:

- Auto tracking (By the using calculated parameters)
- Manual tracking (By the software)

1) Auto Tracking

The auto tracking is performed on the basis of parameters calculated wrt CSP, CPV and alignment data. In this system tracking is seems to be automatically conducted with regard to various calculation made on the basis of iteration calculation. Also it is mathematically calculated that how sun follow a definite path throughout the day and year and this calculation has been utilized as a software calculation and some parameter have been generated and attached to each heliostats for making automatic tracking system. This analog data is converted into the digital form by passing through ADC, microcontroller that is allotted to individual heliostats. After auto tracking the point on the heliostats seem to be a stationary point. After every actuators movement, length of actuators changes that position feed into the file we have created to take calibration. Once the tracker moved 180 degrees, maximum length have been fixed and when it attained the 0 degree minimum length is fixed and it is checked; the system will return to its starting point and enters in horizontal mode.

2) Manual Tracking

In manual tracking we used software named "heliostats conductor Software"; this software is created on python, with the help of this software we can move the solar heliostats in our desired direction on both of its axis, this software uses the parallel port to communicate with the CPU.

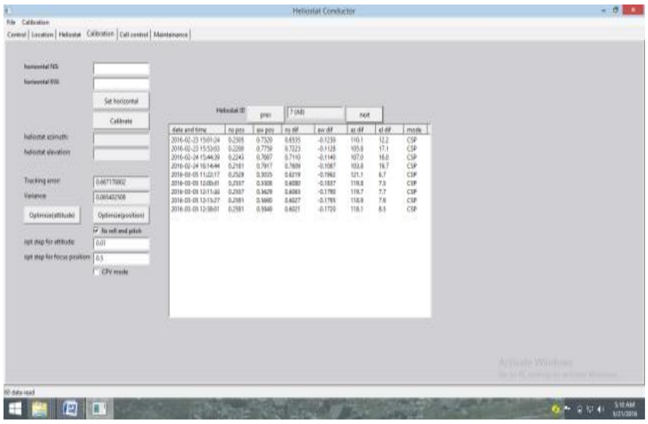

Fig. 8: Calibration reading screenshots

G. Mathematical Calculation Procedure

Focus (receiver) position and heliostat attitude (yaw, roll, pitch) are unknown parameter (column length, arm length, etc. should be measured correctly) For initial value of unknown parameter, tracking error can be calculated. Tracking error is RMS (root mean square) of each error of calibration (az dif and el dif). Then, tracking error is calculated for the different parameters and compares two tracking errors. During optimization process of unknown parameters, I used numerical analysis. That is iterative calculation of tracking error step by step with changing each unknown parameters. Finally, we get heliostat parameters that minimize tracking error.

This is not document because it's not special calculation. Just solving non-linear equation with iterative method.

1) Calculate tracking error and variance with initial parameter
2) Add the specified value (opt step for attitude or opt step for focus position in Calibration tab) to the initial parameter
3) Calculate tracking error and variance again
4) Compare 1. And 3.
5) If the tracking error (or variance) decreases, add more value to the parameter.
6) If the tracking error (or variance) increases, subtract the specified value.
7) Iterate 1~6 and you can get the parameter that minimize tracking error or variance.

H. Iterative Method

In computational mathematics, an iterative method is a mathematical procedure that generates a sequence of improving approximate solutions for a class of problems. A specific implementation of an iterative method, including the termination criteria, is an algorithm of the iterative method.

Initial parameter attitude= (yow, roll, pitch) = (0,0,0) for the time being, variance=0.2. next time, variance is calculated again with attitude (0.01,0,0) if variance become 0.19, then try attitude=(0.02, 0, 0) if variance become 0.18, then try attitude=(0.03, 0, 0) iteration ... if variance get to 0.10 with (0.05,0,0) and next try get to 0.11 with (0.06,0,0), variance is optimized to 0.1 with (0.05,0,0). Same procedure with roll and pitch and Focus position.

Heliostat parameter is calculated with iterative method to minimize tracking error and variance. Tracking error is calculated from difference between manual calibration data and actuator positions calculated from temporary parameter. RMS is used to consider every calibration data from one heliostat. These are what I mean theoretical background and general procedure.

VI. 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 1: Description Cross Linear Tower, Trough, Linear Fresnel

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].

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.

VIII. CONCLUSION

It has been implemented a simple, robust system. A system of easy handling by means of which the solar tracking installation is supervised and its daily movement is controlled, either from a PC through the user, or automatically, increasing the installation working hours and therefore increasing considerably the solar installation performance. The controllers of the installation have been designed and implemented in accordance with the application, demonstrating the versatility, applicability and potential of the control using distributed control networks.

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.

REFERENCE

[1] The World in 2050 Will the shift in global economic power continue? https://www.pwc.com/gx/en/issues/the-economy/assets/world-in-2050-february-2015.pdf
[2] Renewable and Sustainable Energy Reviews 15 (2011) 5169–5175
[3] http://www.esrl.noaa.gov/
[4] Electricity sector in India, https://en.wikipedia.org/wiki/Electricity_sector_in_India
[5] Electricity sector in India, http://www.nosmut.com/Electricity_sector_in_India.html

[6] India targets 1,75,000 mw green power by 2022: Budget, source :Financial chronicle
[7] Budget 2015: India targets 1,75,000 MW green power by 2022, source: The economic times
[8] Renewable and Sustainable Energy Reviews, Concentrating solar power – Technology, potential and policy in India
[9] Development of Concentrating Solar Power (CSP) Plants in India, Website: www.ijetae.com
[10] Ministry of New & Renewable Energy, Jawaharlal Nehru National Solar Mission Phase II – Policy Document, source: http://mnre.gov.in/file-manager/UserFiles/draft-jnnsmpd-2.pdf
[11] Press Information Bureau, Government of India, Cabinet, Revision of cumulative targets
[12] Progress in Development Of High-Temperature Solar-Selective Coating, Proceedings of ISEC2005 2005 International Solar Energy Conference August 6-12, 2005, Orlando, Florida USA
[13] http://stalix.com/solar-energy.htm
[14] Concentrated Solar Power Used For Power Generation, International Journal For engineering Applications And Technology
[15] solar power conversion, engineering ,technology, financing by Oreste Bramanti
[16] energy café, Solar Thermal Technologies, http://cafedeenergy.blogspot.in/2015/01/solar-thermal-technologies.html http://www.eere.energy.gov/basics/renewable_energy/linear_concentrator.html
[17] Cross Linear Solar Concentration System for CSP, research paper by scientist Y. Tamaura http://www.slideserve.com/zoe-noble/solar-thermal-technology-in-india-issues-and-opportunities
[18] Cross linear solar concentration system for CSP and CPV, Y. Tamaura*, S. Shigeta, Q.-L.Meng, T. Aiba and H. Kikura