International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-3, Issue-3, March 2015

A Survey on Recent Technologies in Concentrated Solar Power Generation

P. Mahesh, Y. Venkatrami Reddy, D. Sreedhar

***Abstract*— There are many sources of energy that are renewable and considered to be environmentally friendly and harness natural processes. These sources of energy provide an alternate 'cleaner' source of energy. Now a day's Solar Energy placing vital role in Power Generation. Solar power is one the major source that is available plenty in the earth. We are developing electrical power from solar energy through photo voltaic cells and concentrated solar power technologies. There is a high capacity of sun light but major problems in converting and storing solar power efficiently. We have to increase the efficiency of converting solar power and make it economical. After a system has been established, it will be very difficult to upgrade the systems or change the operation methods. In order to choose the right solar system for a specific geographic location, we want to understand and compare the basic mechanisms and general operation functions of several concentrated solar power technologies that are widely studied. This paper not only tells about the fast developing solar technologies industry, but also may help us avoid long term switching cost in the future and make the solar systems performance more efficient, economical and stable.**

***Index Terms*— Renewable energy, Solar Power, Concentrated Solar Power (CSP) Technologies, Cost analysis, Parabolic trough Collectors, Linear Fresnel Collectors, Solar Tower, Parabolic Dish Reflectors**

I. INTRODUCTION

The study of renewable energy sources has been of global concern to the world, and has led many institutions to undertake research on sustainable approach to meet the challenges of sustainable energy generation. Renewable energy is a clean energy system that has no effect during or after generation on the environment and which this has led to continuous improvement on solar energy for a better way of reducing greenhouse effect in the future. This has also helped developed and developing countries to take full advantage of this free gift of nature to promote ecological and social innovation which will ensure more sustainable economy growth conservation and social stability. A critical challenge that continues to constrain the advancement of many developing countries is the prevalence of poverty. In spite of an abundance of solar energy most developing nations, lack stable power source, due to low technology advancement, poverty, and poor management of existence facilities [20].

Manuscript received March 02, 2015.

P Mahesh, PG Scholar, Department of Computational Engineering in Electrical , Rajiv Gandhi University of Knowledge Technologies , RK Valley –Kadapa, India,+91-8885363278.

Y Venkatrami Reddy, PG Scholar, Department of Computational Engineering in Electrical , Rajiv Gandhi University of Knowledge Technologies , RK Valley – Kadapa, India,+91-8790743414.

D Sreedhar, PG Scholar, Department of Computational Engineering in Electronics and Communication , Rajiv Gandhi University of Knowledge Technologies , RK Valley – Kadapa, India,+91-9885074137.

Solar energy falls on the surface of the earth at a rate of 120 petawatt, (1 petawatt=10^{15}watt). This means all the solar energy received from the sun in one day can satisfied the whole world's demand for more than 20 years [16]. Renewable energy technologies can help countries meet their policy goals for secure, reliable and affordable energy to expand electricity access and promote development. There are several kinds of solar techniques that are currently available [12]. However, each of them is based on quite different concepts and science non-concentrated photovoltaic solar panels or Cells (PV) and concentrated solar power (CSP) are the two most mature technologies. They have been commercialized and expected to experience rapid growth in the future, thus our emphasis will be on these two technologies. The basic idea of photovoltaic effects is simple. Electrons will emit from matter (metals and non-metallic solids, liquids or gases) as a result of their absorption of energy from electromagnetic radiation of very short wavelength, such as visible or ultraviolet light. Electrons emitted in this manner may be referred to as "photoelectrons". First observed by Heinrich Hertz in 1887, the phenomenon is also known as the "Hertz effect" [8] – [10].

Major types of photovoltaic panels are Crystalline Silicon, Thin Films (Amorphous Silicon) but this technology is an old technology by using this technology we can't generate large amount of power so to generate large amount of power we go for concentrated solar power methods [14]. In this paper, the various technologies employed for generating large amount of power to corresponding technology gives clear idea about concentrated solar power techniques. For this purpose, in Section II a brief study of Concentrating Solar Power, mechanism of how to track the sun and advantages, disadvantages of CSP system. In Section III the various types of technologies based on line focusing and point focusing .Also generation of power by using these technologies. In Section IV

Discussion and Comparison regarding to these technologies.

The following figure shows that the availability of solar resources in the world so we can go for concentrated solar power technologies for generating large amount of power [7].

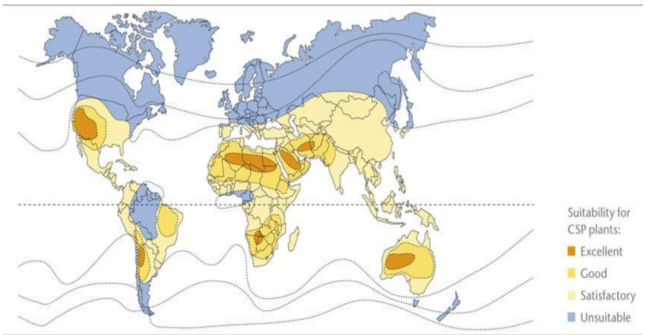

Fig. 1. Solar resources for CSP technologies

Today, concentrated solar power plants are more economical than photovoltaic technologies at sites where global irradiations is more. Although CSP is preferable in some regions, they are abundant enough to support world demand [13].

II. CONCENTRATING SOLAR POWER

To extract electricity from solar radiation, the power plants use the technology of solar concentration. The concentration depends on the mirror surfaces and receiver area. But if the mirrors are fixed, it will reach its maximum at a specific time of day and will decline around this time. To limit this decrease most systems have a mechanism to track the sun. The orientation is tailored to optimize the position of the reflecting surface relative through the sun. As the sun's position is characterized by two values: the height ranging from 0 to 90 °, and azimuth ranging from-180 ° to +180 °, two orientation axes of the mirrors meet the monitoring purpose. But to optimization of cost, a choice of operating flexibility may lead to adopt one parameter setting, monitoring or approximate, to the detriment of the average conversion factor [9].

There are four main types of Concentrating Solar Power (CSP) technology used to concentrate and collect sunlight in order to turn it into heat, see Fig 1

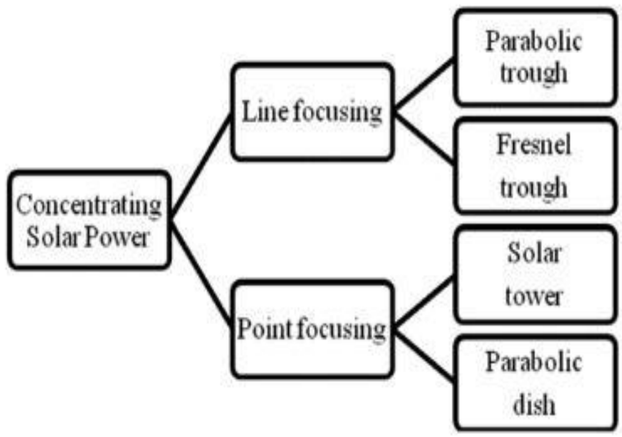

Fig. 2. Types of concentrated solar power technologies

In these technologies, the solar concentrators focus sunlight into a point or a line. In this paper we are interested in the first type and second type. Unlike the photovoltaic solar cells, converting energy from sunlight to electricity by CSP systems is based on the application of heat engine rather than photovoltaic effect which is directly transfer photon energy into electrical energy [21].

Advantages of CSP Systems:

- Large installations can be efficient and can pay for themselves if an economy of scale is achieved. Advances in system design have made these power plants more efficient at producing electricity but since they only collect solar energy when the sun is shining.
- Solar farms can be placed in hot, dry inhospitable locations where human and wildlife is sparse.
- The entire system uses established technology that is readily available (mirrors, tubes and electrical generators).
- These units produce electricity during the day when air-condition loading is high. These clean-running, daytime power plants help supplement other primary electrical generation sources.
- The thermal efficiency is greater because of the small heat loss area relative to the receiver area.

Disadvantages of CSP Systems:

- Expensive transmission lines need to be installed in remote desert locations to get the useful energy to market. Since electrical production may not be continuous, it takes a longer time for CSP systems to pay for themselves.
- These units are most efficient during the daylight hours and cannot be relied upon as primary electrical sources. Even the systems that use heat storage techniques may stop producing electricity if it's overcast for a number of days.
- Small dish/engine systems cannot be economically used in a backyard to power a house. It is currently too expensive to build a system with a mirror alignment system and a Stirling engine.
- They are not as cheap to operate as conventional hydro, nuclear or coal-fired power plants.

In relatively cloudless areas, the concentrating collector may capture more radiation per unit of aperture area than a flat panel collectors (FPC). It will be more preferable to adopt concentrating collectors in arid or semi-arid area.

III. CSP TECHNOLOGIES

Concentrating solar power (CSP) is a power generation technology that uses mirrors or lenses to concentrate the sun’s rays and in most of today’s CSP systems to heat a fluid and produce steam. The steam drives a turbine and generates power in the same way as conventional power plants. Other concepts are being explored and not all future CSP plants will necessarily use a steam cycle [2] – [5].

A wide range of concentrating technologies exists. The most developed are

- Parabolic trough collectors (PTC)
- Linear Fresnel collectors (LFR)
- Solar towers (Heliostat field collectors)
- Parabolic dish reflectors (PDR)

A. Parabolic trough collectors

A parabolic trough system consists of many long parallel rows of curved mirrors that concentrate light onto a receiver pipe positioned along the reflectors focal line, as shown in Fig 2. The troughs follow the trajectory of the sun by rotating along their axis to ensure that the maximum amount of sunlight enters the concentrating system. The concentrated solar radiation heats up a fluid circulating in the pipes, typically synthetic oil or molten salt, to temperatures of up to 750^{o}F.The hot oil is pumped to heat exchangers to generate steam, which is used to drive a conventional steam turbine generator. A schematic diagram of a solar power plant using parabolic trough concentrators is shown in Fig 2.

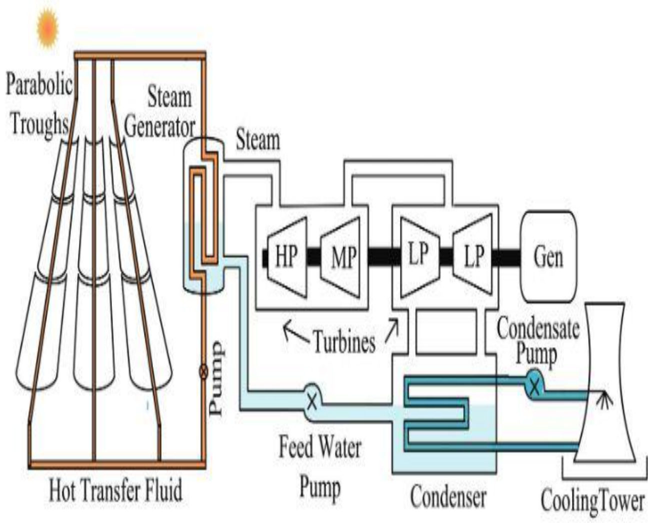

Fig. 3. Schematic diagram of a solar power plant with parabolic trough concentrators

Solar power is intermittent and is not available overnight; therefore, some solar power plants are designed to operate as hybrid solar/fossil plants. As hybrids, they have the capability to generate electricity during periods of low solar radiation. The new parabolic trough plants use molten salt for the heat transfer medium, which is cheaper and safer than oil. Also, because salts are an effective storage medium, the spare solar power is used in the form of heated molten salt in storage tanks, for use during periods when solar power is not available. This makes the CSP technology truly dispatch [13].

One of the largest parabolic trough power plants is the Solar Energy Generating Stations (SEGS) in California's Mojave Desert. It consists of nine solar power plants that have a combined capacity of 354 MW. Over the past 20 years these plants have delivered power with a high degree of reliability, and they continue to operate well in the Mojave Desert [4].

B. Linear Fresnel Collectors

Fresnel collectors have two variations: the Fresnel lens collector (FLC) and the linear Fresnel reflector (LFR). The former is made from a plastic material and shaped in the way shown to focus the solar rays to a point receiver, whereas the latter relies on an array of linear mirror strips that concentrate light onto a linear receiver. The LFR collector can be imagined as a broken-up parabolic trough reflector but unlike parabolic troughs, the individual strips need not be of parabolic shape. The strips can also be mounted on flat ground (field) and concentrate light on a linear fixed receiver mounted on a tower. A representation of an element of an LFR collector field is shown in Fig 3. In this case, large absorbers can be constructed and the absorber does not have to move. The greatest advantage of this type of system is that it uses flat or elastically curved reflectors, which are cheaper than parabolic glass reflectors. Additionally, these are mounted close to the ground, thus minimizing structural requirements [6].

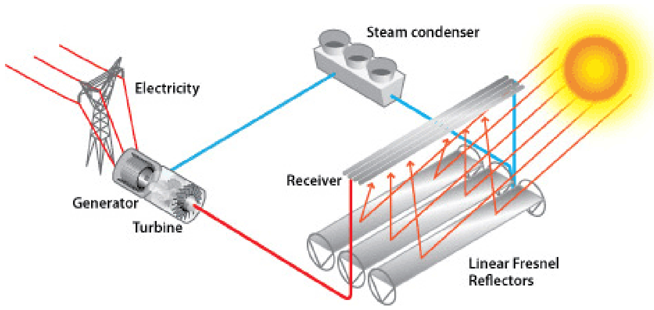

Fig. 4. Schematic diagram of a solar power plant with linear Fresnel reflectors

C. Solar Towers

Solar Towers (Heliostat field collector) can be used for extremely high inputs of radiant energy to reflect their incident direct solar radiation onto a common target as shown in Fig 4. This is called the heliostat field or central receiver collector. By using slightly concave mirror segments on the heliostats, large amounts of thermal energy can be directed into the cavity of a steam generator to produce steam at high temperature and pressure [5].

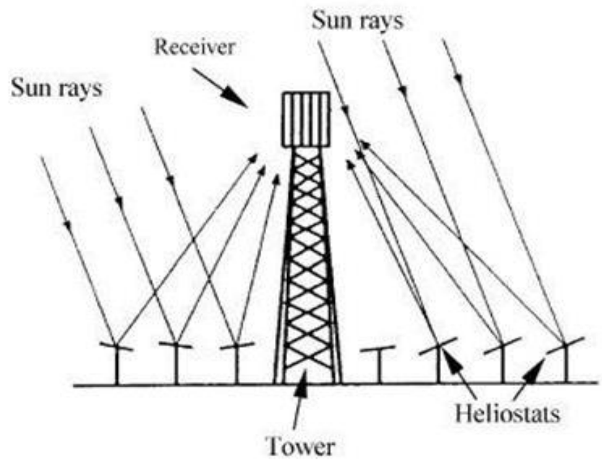

Fig. 5. Schematic diagram of a Solar Tower

The average solar flux impinging on the receiver has values between 200 and 1000 kW/m^2.The concentrated heat energy absorbed by the receiver is transferred to a circulating fluid that can be stored and later used to produce power. Central receivers have several advantages:

- They collect solar energy optically and transfer it to a single receiver, minimizing thermal-energy transport requirements.
- They typically achieve concentration ratios of 300 –1500 and are highly efficient, both in collecting energy and in converting it to electricity.
- They can conveniently store thermal energy.
- They are quite large (generally more than 10 MW) and thus benefit from economies of scale.

D. Parabolic dish reflectors

Parabolic dish reflector is a point-focus collector that tracks the sun in two axes, concentrating solar energy onto a receiver located at the focal point of the dish. The dish structure must track fully the sun to reflect the beam into the thermal receiver.

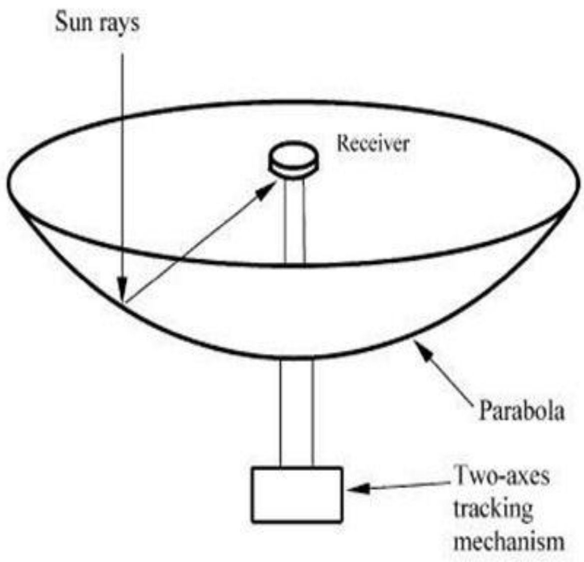

Fig. 6. Schematic diagram of a Parabolic dish reflector

The receiver absorbs the radiant solar energy, converting it into thermal energy in a circulating fluid. The thermal energy can then either be converted into electricity using an engine-generator coupled directly to the receiver, or it can be transported through pipes to a central power-conversion system. Parabolic dish systems can achieve temperatures in excess of 1500^{o} C [11].

Parabolic dishes have several important advantages:

- Because they are always pointing at the sun, they are the most efficient collector systems.
- Typically, they have a concentration ratio in the range of 600–2000 and are highly efficient at thermal-energy absorption and power conversion systems.
- They have modular collector and receiver units that can either function independently or as part of a larger system of dishes.

Parabolic-dish systems that generate electricity from a central power converter collect the absorbed sunlight from individual receivers and deliver it via a heat-transfer fluid to the power-conversion systems. The need to circulate heat transfer fluid throughout the collector field raises design issues, such as piping layout, pumping requirements, and thermal losses. The Stirling engine is the most common type of heat engine used in dish-engine systems. For this system, certain level of reliability and mass production still need to be achieved.

IV. Discussion and Comparison

E. Comparison

These CSP technologies differ significantly from one another, not only with regard to technical and economic aspects, but also in relation to their reliability, maturity and operational experience in utility scale conditions.

TABLE I
Comparison of various technologies

Terms	Parabolic Trough	Linear Fresnel	Solar Tower	Parabolic Dish
Typical capacity(MW)	10-300	10-200	10-200	0.01-0.03
Operating temperature(^{o}c)	350-550	390	250-565	550-750
Plant peak efficiency (%)	14-20	18	23-35	30
Annual solar to electricity efficiency (%)	11-16	13	7-20	12-25
Collector concentration	70-80 suns	>60 suns	>1000 suns	>1300 suns
Technology development risk	Low	Medium	Medium	Medium
Storage system	Indirect two-tank molten salt at (380^{o}C)	Short-term pressurized steam storage	Direct two-tank molten salt(550^{o}C)	No storage for Stirling Dish
Grid stability	Medium to High	Medium	High	Low
Cycle	Superheated Rankine steam cycle	Saturated Rankine steam cycle	Superheated Rankine steam cycle	Stiriling
Maximum slope of solar field	<1-2	<4	<2-4	10%
Suitability for air cooling	Low to Good	Low	Good	Best
Application type	On grid	On grid	On grid	On grid/ Off grid

Parabolic trough plant are the most widely commercially Deployed CSP plant, but are not a mature technology and Improvements in performance and cost reductions are Expected. Virtually all PTC systems currently deployed [15]. Do not have thermal energy storage and only generate Electricity during daylight hours. Most CSP projects currently under construction or development are based on parabolic trough technology, [18] as it is the most mature technology and shows the lowest development risk. Parabolic troughs and solar towers, when combined with thermal energy storage, can meet the requirements of utility-scale, schedulable power plant.

F. Cost Analysis

The formula used for calculating the LCOE of renewable energy technologies is

$$LOCE := \frac{\sum_{t=1}^{n} \frac{(I_t + M_t + F_t)}{(1+r)^t}}{\sum_{t=1}^{n} \frac{(E_t)}{(1+r)^t}}$$

Where

LCOE =the average lifetime levelised cost of electricity Generation.

I_t=investment expenditures in the year t.

M_t=operations and maintenance expenditures in the year t

F_t=fuel expenditures in the year t

E_t=electricity generation in the year t r = discount rate; and

n = life of the system.

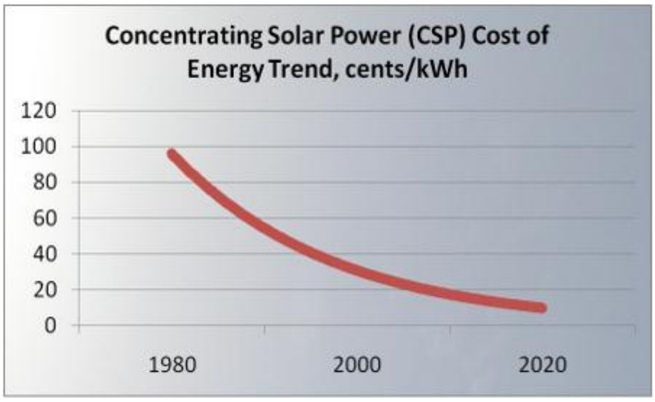

Fig. 7. Graph verses cost of CSP to Energy

The current CSP market is dominated by parabolic trough technology. More than 80% of the CSP power plants in operation or under construction are based on this technology. As a consequence, most of the available cost information refers to parabolic trough systems. The cost data for parabolic trough systems are also the most reliable, although uncertainties still remain, because it is the most mature CSP technology [17].

G. Cost Reduction Potentials of Parabolic trough CSP

The opportunities for cost reductions for CSP plant are good. The commercial deployment of CSP is in its infancy and as experience is gained, R&D advances, plants get bigger, mass production of components occurs and increased competition in technology providers develops, [19] costs will come down. However, significant investment in further R&D and deployment will be required to realise these cost reductions.

The key areas where cost reductions need to be achieved are in:

1) *The solar field:* mass production and cheaper components as well as improvements in design can help to reduce costs.

2) *The storage system:* This is closely tied to the heat transfer fluid, as higher temperatures, notably from solar towers will reduce the cost of thermal storage the existing Molten salt storage system the solution for that is Latent heat storage thermo cline storage, new storage materials such as concrete ,sand or others gives best solution for storage system [1].

3) *The heat transfer fluid:* new heat transfer fluids and those capable of higher temperatures will help to higher storage possibilities. The existing heat transfer fluids is synthetic oil to get high temperature fluids like molten salt allow high temperature s while direct steam generation allows reduced water and no heat exchangers.

4) *Materials:* Material nothing but mirrors the existing mirrors are curved glass mirrors if we replace these mirrors with Metallic reflectors coated polymer film will reduce the Cost and gives high reflectivity.

5) Collector: The existing Collectors are PTC with 5-6 m apertures. If we replace these collectors with variety of collector substructures, different collector widths 1-10 m large apertures for PTCs.

V. CONCLUSION

In this paper it is natural that CSP would be compared to solar PV when assessing the future of the technology because they are both solar powered systems. There are three main factors considered when power utilities are debating on which renewable energy technology to generate electricity from. They are

i. Competitive energy Cost
ii. Ancillary Services
iii. Delivery upon Demand

Leading researchers argue that CSP is in a position to perform better than solar PV in all the three categories especially since the inexpensive thermal storage offered by CSP systems allow for better delivery of energy upon demand. CSP system installations are expected to reach about 10.8 GW and PV systems to reach 45.2 GW by 2014 while the two systems reported 0.29 GW and 7.0 GW in 2009 respectively This shows that the market growth prospects of CSP systems are much faster than PV since CSP systems are expected to increase 37 times while PV will increase about 6.5 times. Other factors such as availability of land for CSP systems may limit the developments, but only time can tell.

So Photo voltaic solar panels and Concentrated Solar power are two dominant forms of solar technology that can provide electricity to society. More importantly, connecting the sectors to the grid, CSP is more predictable energy and able to provide network ancillary services while PVs need more control features or additional equipment. In these two the Second CSP technology placing a vital role in generation of larger amount of power, through this we can connect this power to grid by this demand of power will be reduces. Among all CSP technologies the global market has been dominated by Parabolic trough collector plants which accounts of 90% of CSP plants. By employing good Solar field, Storage system, Heat transfer fluids, Mirrors and collectors discussed above we will get a better efficiency and Reduction in cost of Parabolic – trough plants.

ACKNOWLEDGMENT

The authors would like to thank Asst Prof P Ravi kumar, Co-ordinator of M.Tech RGUKT RK Valley, Prof. K Venugopal Reddy, Director RGUKT RK Valley and Prof.S.Satya Narayana, Vice chancellor RGUKT for their consistent support to complete this work

REFERENCES

[1] Cabeza, L. F., Sloe, C., Castell, A., Oro, E., Gil, A., 2012. Review of solar thermal storage techniques and associated heat transfer technologies, Proceeding of IEEE 100, 525-538.
[2] R Sioshansi and P Denholm, "The Value of Concentrating Solar Power and Thermal Energy Storage," *IEEE Transactions on Sustanable Energy*, vol. 1, no. 3, pp. 173-183, October 2010.
[3] Herrmann, U., Kearney, D. W., 2002. Survey of therma L energy storage for parabolic trough power plants, Solar Energy Engineering, 124,145-152.
[4] H Muller-Steinhagen, Freng Tried, and Franz Trieb, "Concentrating Solar Power," A review of the technology, no 18, February 2004.
[5] L Stoddard, J Abiecunas, and R O'Connell, "Economic, Energy, and Environmental Benefitsof Concentrating Solar Power in California,"

NREL, SR-550-39291, 2006.
[6] Environmental and Energy Study Institute (EESI), "Concentrated Solar Power," Fact Sheet, August 2009
[7] German Solar Industry Association (BSW-Solar) and European Photovoltaic Industry Association, *Solar Photovoltaic: A Powerful Way to Combat Climate Change*. 2011
[8] Blundell, Katherine and Blundell, Stephen, Concepts in Thermal Physics, 2009
[9] R A Manuel, "Concentrating Solar Thermal Power," CIEMAT-PlataformaSolar de Almeria, Handbook of Energy Efficiency and Renewable Energy, 2007.
[10] Chen, Jincan,"Thermodynamic Analysis of a Solar-driven Thermoelectric Generator," Journal of Applied Physics, Volume 79, Issue 5, March 1, 1996
[11] Fan, Hongnan, Singh, Randeep, and Akbarzadeh,Aliakbarm, "Electric Power Generation From Thermoelectric Cells Using a Solar Dish Concentrator," Journal of Electronic Materials , 2011
Madaeni, S. H., Sioshansi, R. and Denholm, P., 2012, *"How Thermal Energy Storage Enhances the Economic Viability of Concentrating Solar Power," Proceedings of the IEEE* 100(2) 335-47.
[12] Fan-Tai Kong, Song-Yuan Dai, and Kong-JiaWang, "Review of Recent Progress in Dye-Sensitized Solar Cells," Advances in OptoElectronics, 2007.
[13] Renewable Energy Market Transformation (REMT) Unit, "Concentrated Solar Power," The Concentrated Solar Power Workshop, September 2009.
[14] D Mills, "Advances in Solar thermal electricity technology," Solar Energy, vol. 76, pp. 19-31, 2004
[15] C. Turchi, M. Mehos, C. K. Ho, and G. J. Kolb, "Current and Future costs for parabolic trough and power tower systems in the us market," National Renewable Energy Laboratory, Tech. Rep. NREL/CP-5500-49303, October 2010.
[16] Green, M.A., Emery, K. Hishikawa, Y., Warta, W., Dunlop, E.D."Solar Cell Efficiency Tables (Version 38)," Progress in Photovoltics, 2011.
[17] F Trieb, C Schillings, M O'Sullivan, T Pregger, and C Hoyer- Klick, "Global Potential of Concentrating Solar Power," in SolarPaces Conference, Berlin, 2009.
[18] YogiD.G, KreithF, KreiderJ.F. Principles of solar engineering. 2nd Edition: Taylor & Francis.pp:138, 429
[19] S. Kurtz, Technical Report, Opportunities and Challenges for Development of a Mature Concentrating Photovoltaic Power Industry, NREL/TP-520-43208 Revised November 2009
[20] M. R. Milligan, "Measuring wind plant capacity value," N Atonal Re-newable Energy Laboratory, Tech. Rep. NREL/TP-441-20493, 1996.
[21] Duffie J.A., BeckmanW.A. Solar Engineering of Thermal Processes. 2nd edition. New York: John Wiley and Sons, Inc., 1991.

P Mahesh is currently pursuing Master of Technology in Computational Engineering in Electrical, Rajiv Gandhi University of Knowledge Technologies, RK Valley Kadapa, Andhra Pradesh. Earlier he received his B.Tech degree in Electrical and Electronics Engineering from Sri Venkateswara College of Engineering and Technology, Chittoor in 2012. His current research interests include Solar Power Generation Techniques.

Y Venkatrami Reddy is currently pursuing Master of Technology in Computational Engineering in Electrical, Rajiv Gandhi University of Knowledge Technologies, RK Valley Kadapa, and Andhra Pradesh. Earlier he received his B.Tech degree in Electrical and Electronics Engineering from Annamacharaya Institute of technology and Sciences, Rajampeta in 2012. His current research interests include Solar Power Generation Techniques.

D Sreedhar is currently pursuing Master of Technology in Computational Engineering in Electronics and Communication, Rajiv Gandhi University of Knowledge Technologies, RK Valley Kadapa, Andhra Pradesh. Earlier he received his B.Tech degree in Electronics and Communication Engineering from KSRM College of Engineering , Kadapa in 2012. His current research interests include Solar Power Generation Techniques.