A Review of Concentrating Solar Power (CSP) in Centre Indian Environment

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Abstract: **India has an abundance of solar energy. With about 300 clear, sunny days in a year, India's theoretically calculated solar energy incidence on its land area alone is about 5,000 trillion kilowatt-hours (kWh) per year (or 5 EWh/yr). The solar energy available in a year exceeds the possible energy output of all fossil fuel energy reserves in India. The daily average solar power plant generation capacity over India is 0.25 kWh per m^2 of used land area, which is equivalent to about 1,500–2,000 peak (rated) capacity operating hours in a year with the available technologies. However, the focus on solar energy in India is mainly on the Photovoltaic (PV) panel to generate electricity. There is still lack of thorough investigation in implementing the solar thermal, such as the Concentrating Solar Power (CSP) in Indian environment. This paper reviews the CSP technology and the potential of developing CSP plant in the Indian environment by taking into account the Direct Normal Irradiance (DNI) and a few geographical aspects.**

***Keywords*: Concentrating Solar Power (CSP), Direct Normal Irradiance (DNI), Photovoltaic (PV).**

1INTRODUCTION

The standard of living of the people of any country is considered to be proportional to the energy consumption by the people of that country. In one sense, the disparity one feels from country to country arises from the extent of accessible energy for the citizens of each country. Unfortunately, the world energy demands are mainly met by the fossil fuels today. The geographical non equi-distribution of this source and also the ability to acquire and also control the production and supply of this energy source have given rise to many issues and also the disparity in the standard of living. To illustrate the points that have been mentioned, it is necessary to analyze some dataSolar energy research began at 1971 at a time when renewable energy and ecological imperatives were not high on the social or political agendas.

The renewable energy sources are not broughtinto main stream energy resources though occasionally we hear the use of low quality biomass as a source in some form or the other. The carbon dioxide emission must be controlled in the vicinity of 600 to 650 pp min the period of 2030 to 2080. The exact slope of the curve isnot a matter of concern the cumulative amount of the carbon dioxide emission will be a factor to reckon with.

Therefore the alternative for energy supply should include fossil fuel with carbon dioxide sequestration, nuclear energy and renewable energies. Possibly fusion and also hydrogen based energy carrier system will evolve. However, the costs involved may even force the shift to the use of coal as an energy source in countries like India and China.

Fig.1 illustrates the world solar energy map. Most of the countries, except those above latitude 451 N or below latitude 451 S, are subject to an annual average irradiation flux in excess of 1.6 MWh/m^2, with peaks of solar energy recorded in some ‘‘hot’’ spots of the Globe, e.g., the Mojave Desert(USA),the Sahara and Kalahari Deserts (Africa), the Middle East, the Chilean Atacama Desert and North-western Australia.

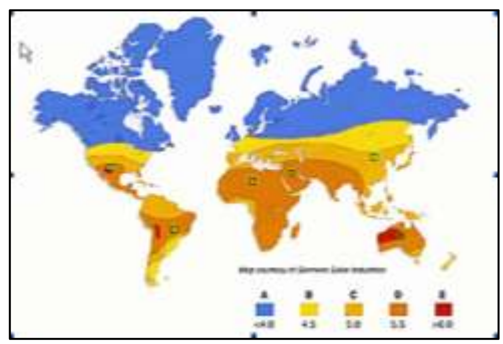

Figure 1 World Solar Energy Map

2 Concentrated Solar Plant (CSP)

In present day many of the power plants uses fossil fuels as a heat source aim to boil water. The steam from the boiling water is then used to spins large turbine, which drives a generator to produce electricity. Now days new generation of power plants along with concentrating solar power systems utilize the sun as a heat source. The three majorkinds of concentrating solar power systems are: linear concentrator, power tower systems, and dish/engine. CSP can be a competitive source of large power production in peak and inter-mediate loads in the sunniest regions by2020, and of also as base load power by2025to2030.

Linear concentrator systems effectively use the sun's energy using long rectangular, U-shaped (curved) mirrors. The mirrors are sloped toward the sun, which focused sunlight on tube shape receivers that run the length of the mirrors. The reflected sunlight transfers the heat to the fluid flowing through the tubes. The hot fluid then is used to boil water in a conventional steam-turbine generator to produce electricity.

There are two major types of linear concentrator systems: parabolic trough systems, in which the receiver tubes are positioned along the line of focus of each parabolic mirror; and linear Fresnel reflector systems, in which one receiver tube is placed above several mirrors to allow the mirrors greater movement in tracking the sun.

But in the case of dish/engine system it uses a mirrored dish which is similar to a very large satellite dish, although to minimize costs, the mirrored dish is usually consist many smaller flat mirrors which forms dish shape. The dish-shaped surface aims and focuses sunlight onto a thermal receiver, which absorbs the heat and after collecting transfers it to the engine generator. The most common type of heat engine used today in dish/engine systems is the Stirling engine.

A power tower system uses a large field of flat, sun-tracking mirrors called heliostats to focus and concentrate sunlight onto a receiver on the top of a tower. A heat-transfer fluid which has been heated in the receiver is then used to generate steam, which, also, is used in a conventional turbine generator to generate electricity.

2.1 Principles

Basically, the process of solar thermal power generation is realised within the following steps:

a. Concentrating solar radiation by means of a collector system;
b. Increasing radiation flux density (i.e. concentrating of the solar radiation onto areceiver), if applicable;
c. Absorption of the solar radiation (i.e. conversion of the radiation energy intothermal energy (i.e. heat) inside the receiver);
d. Transfer of thermal energy to an energy conversion unit;
e. Conversion of thermal energy into mechanical energy using a thermal engine(e.g. steam turbine)
f. Conversion of mechanical energy into electrical energy using a generator.

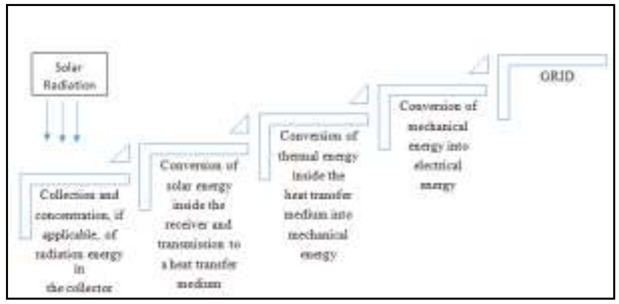

Figure2 Energy conversion chain of solar thermal power generation

2.2 Parabolic trough collector technology

Parabolic trough power plants as line focusing powerplants. The line focusing solar fields of parabolic trough and linear Fresnel collectorsreflect the incident radiation on an absorber positioned in the focal line of theconcentrator. The collector tracks the sun in one axis. Due to this "onedimensionalconcentration" the geometric concentration factors of 15 to 30 areconsiderably lower than those of two-dimensional collectors discussed above.

This is why lower temperatures are achieved when compared to solar tower powerplants. However, this disadvantage is compensated by lower specific costs as wellas a simpler structure and maintenance.

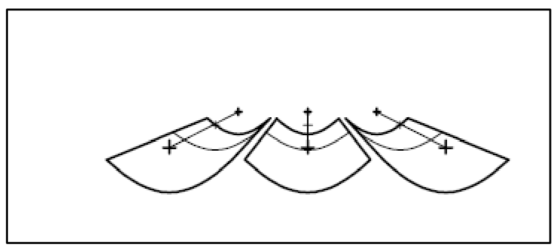

Figure3 Principles of parabolic trough collectors

This collector type is characterized by a parabolicreflector which concentrates the incident radiation onto a tube positioned in thefocal.The reflector itself may either consist of one surface provided with a reflectinglayer (metal foil, thin glass mirrors) or of several curved mirror segments arrangedin a truss-type structure; the latter variant is commercially applied. Collector's aremounted on a mounting structure and track the sun's diurnal course by a singleaxissystem following the longitudinal axis.

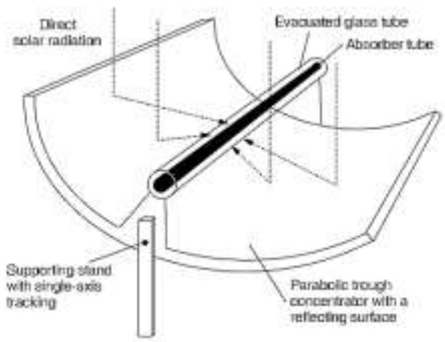

Figure 4 Working principle of a parabolic trough

2.3 Absorber / Heat Collecting Element (HCE)

Individual horizontal tubes areused as absorbers in the focal line of the collectors; for Fresnel collectors also tubegroups may have to be used due to their wider focal line. Today's stainless steelabsorber tubes of parabolic trough collectors (i.e. Heat Collecting Element (HCE))are enclosed in an evacuated glass tube to minimize heat losses. In caseof parabolic trough collectors the vacuum also serves to protect the sensitivehighly selective coating. Nowadays, such selective coatings remain stable up totemperatures of 450 to 500 °C; solar absorption is above 95 %, and at a temperatureof 400 °C emissivity is below 14 % /5-18/.

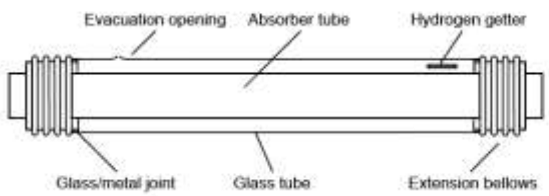

Figure 5 Absorber type parabolic trough collector

2.3 Heat transfer medium

To date, high-boiling, synthetic thermal oil has beenapplied as heat transfer medium in the absorber tubes. Due to the limited thermalstability of the oil, the maximum working temperature is limited to scarcely400 °C. This temperature requires to keep the oil pressurized (approximately 12 to16 bar).As an alternative, molten salt has been proposed as heat transfer medium.

3 COLLECTOR FIELDS

Nowadays, collector fields are composed of a certain number ofloops of an approximate length of 600 m each. These loops are connected to onefeed ("cold header") and one discharge line ("hot header") each. Collectors arenorth-south oriented to allow for high and constant energy yields.

4 COMPARISON OF CSP TECHNOLOGY

All of the CSP technologies can generate clean energy with no fuel cost. The only drawback that concentrating solar power plants have on the environment is land use. To be able to generate high electrical energy, more land is needed for the plant. Although the amount of land a CSP plant occupies is larger than that of a fossil fuel plant, both types of plants use about the same amount of land as fossil fuel plants utilize additional land for mining and exploration as well as road building to reach the mine [7]. Each of CSP technology has its own value proposition and different deployment optima. Table 1 shows the different CSP technologies. The parabolic dish has the highest efficiency, 18-25% but its hybrid operation is still in the R&D phase. Solar tower efficiency is the second highest which is around 14-17% and has the highest operating temperature of High Temperature Fluid (HTF) 1000° c. The efficiency and the operating temperature HTF of Linear Fresnel is the lowest but the cost for linear Fresnel is cheaper than the others CSP systems. Even though Parabolic Trough efficiency is 10-15%, it has the lowest material demand; good land-use factor, modularity, thermal storage and others. Which make parabolic trough the most popular CSP option. However, among the CSP technologies, parabolic trough is the most mature. Parabolic trough has a total capacity of 354 MW and become the largest operating solar plant in the world [7].

Table 1. Different CSP Technologies

Technology	Temperature	Hybrid 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%

Changes in global renewable energy markets, investments, industries and policies have been so rapid in recent years. The cost for producing electricity from renewable resources is traditionally higher than producing electricity from coal or natural gas. However, as renewable technologies attain commercial viability and enter the mainstream market, their price per kilowatt hour is usually decreasing.

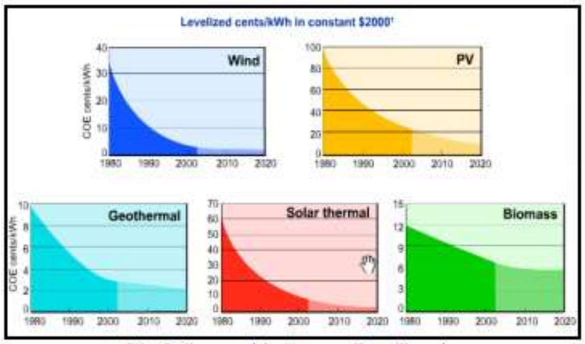

Fig 5 Renewable Energy Cost Trends
Source: NREL Energy Analysis Office

5 CONCLUSIONS

India is located in the tropical regions with its own characteristics, such as wind speed, rapid change of clouds, air, thunder storm and medium humidity level. All of these limited conditions will affect the performance of the CSP system. Therefore, an innovative development and research of CSP should be carried out in Indian environment with detail considerations both on the technical and economic aspects. The research will give big impact not only for India but for other countries which aim to understand and explore CSP technology and the performance in tropical environment.

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