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A Review On Concentrated Solar Power Plants

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Abstract: *Regarding energy storage concentrated solar power plants (CSP) are gaining interest as Parabolic Trough Collectors (PTC) or Solar Tower Collectors (STC). In INDIA electricity generated by CSP is increasing with high rate in every year. On cloudy days CSP's having short term variations and also at night they can't provide energy and hence Thermal Energy Storage (TES) or Backup System (BS) is used to operate continuously. For optimum design and operation of CSP throughout year, an accurate estimation of solar irradiation is needed as well as defining the required TES or BS. INDIA has solar radiation of 1700 – 1900 kWh per kilowatt peak with more than 300 clear sky days therefore INDIA has higher potential for solar electricity generation per watt setup, The paper reviews CSP technology and design, PTC design, STC advantages, adopted model approach and equations.*

Keywords: *Parabolic Trough Collectors (PTC), Solar Tower Collectors(STC), Irradiation, Concentrated Solar Power Plant (CSP), JNNSM (Jawaharlal Nehru National Solar Mission), MNRE (Ministry of New and Renewable Energy).*

I. Introduction

Energy demand is increasing day by day, and the nonrenewable energy resources is depleting with alarming rate. Hence, it is necessary to find the alternative source of energy i.e. renewable energy. These are ecofriendly and easily available on the earth [1]. The world's 80% energy is supplied by the fossil fuels, and their maximum uses will be serious issue in near future. Developing countries also have international pressure to limit the carbon emission along with continue their nation development programs [2]. India is one of leading developing country where economic energy utilization rate has grown considerably in past few decades. India relies strongly on fossil fuels for producing required power. The contribution of coal is of 53.4% of the total power production, hydropower 22.6%, gas 10.6%, atomic energy 2.8%, oil 0.6%, and non-conventional energy resources 10%. To reduce energy supply and demand gap, it is very important to opt renewable energy as alternative energy sources. India is world fifth largest renewable energy based electricity generator [3]. There is abundant availability of solarradiation of 1700–1900 kW h per kilowatt peak for more than 300 clear sky days in year. Electricity can be generated from solar energy in two ways. One is by photovoltaic and another one is concentrated solar power. India has immense opportunity for the development of the CSP based plants. The total installed capacity in India is 12,288.83 MW till March 31, 2017. Among all the states, Rajasthan is the leader in the utilization of the CSP based technologies with installed capacity of 1812.93 MW, then Gujarat and Tamil Naidu with 1249.37 MW and1691.83 MW respectively. In the India, the growth of CSP based plant is very rapid. In the 31 March 2015, the total installed capacity of CSP based plant was only 3743.97 MW. Hence in the two years, the installed capacity is being increased by four times in the two years. [4].

More energyfromthesunlightstrikestheearthin1hthanall of the energy consumed by humans in an entire year. Infact, solar energy dwarfs all there newable and fossil-based energy resources combined. We need energy–electrical or thermal–but in most cases where and when it is not available. Low cost, fossil-based electricity has always served asasignificant cost competitor for electrical power generation. To provide adurable and widespread primary energy source, solar energy must be captured ,store dand used inacost- effective fashion. Solar energy isofunsteady nature,both within the day(day– night, clouds)and within the year(winter–summer).The capture and storage of solarenergy is criticali fasignificant portion of the total energy demand need tobe provided by solar energy. Fig. 1 illustrates theworldsolarenergymap.Mostofthe countries, exceptthoseabove latitu de 451N orbelowlatitude 451S, are subject to anannual average irradiation flux in excess of 1.6 MWh/m2, with peak sof solarenergyrecordedinsome''hot'' spots of the Globe,e.g.,the MojaveDesert(USA), the Saharaand Kalahari Deserts (Africa), the Middle East, the Chilean Atacama Desert and North-western Australia.

II. Concentrated Solar Power Plant

Parabolic trough system:

Concentrated solar power can also be divided into two waysnamely: line focus and point focus.
Parabolic trough collector (PTC)system is working on single axis and has line focus. The completesystem

consists of: mirror, receiver tube and focal line [15]. The sun raysstrike on the mirror; mirrors reflect sun light on black coated metallic tube (absorber) which becomes hot and transfer heat energy to heat transfer fluid flowing inside absorber tube. Absorber tube is situated just above the mirror. The reflector is used to tracking the sun during the daylight and following via single axis. Heat transfer fluid pumped via heat exchanger to produce steam to rotate the turbine and generator [12]. The receiver tube attains temperature around 400 °C. There are many parallel rows of troughs situated across the solar field. The first parabolic trough collector type concentrated solar power plant of 500 kW capacity was developed at Egypt in 1912. After this success story, there were many developments in this area and the 90% of the global CSP market is being dominated by the PTC system [15].

Parabolic dish system:

Parabolic dish is working with point focus and follow the two axes. Receiver is situated at the focal point. Heat transfer fluid gets heated up to 750 °C. Receiver is attached with the turbine and generator, which is used to convert heat into electricity. The capacity of this type plant is vary from 0.01 to 0.4 MW. The efficiency of dish system is more than the trough system, as it is working with point focus i.e. mirror is always pointed to the sun. Thermal efficiency is between 25 to 30%. Themaximum 1500 °C temperature can be achieved by dish system [12].

The selective advantages of dish system are:

1. These are the most effective collector systems due to pointing technology.
2. It has the concentration ratio from 600 to 2000 and they have effective thermal energy absorption.
3. It has modular collector and receiver system; therefore they can perform individually without the help of any system [13].

Solar power tower:

Solar power tower also known as heliostat field collector or central receiver based solar collector. A heliostat field collector (HFC), i.e., Heliostats are flat or slightly concave mirrors that follow the sun in a two axis tracking and, reflect and concentrate the sun rays on to a central receiver placed in the top of a fixed tower [5,6]. In the central receiver, heat is absorbed by a heat transfer fluid (HTF), which then transfers heat to heat exchangers that power a steam Rank in e power cycle. Some commercial tower plants now in operation use direct steam generation (DSG), others use different fluids, including molten salts as HTF and storage medium [6]. The concentrating power of the tower concept achieves very high temperatures, thereby increasing the efficiency at which heat is converted into electricity and reducing the cost of thermal storage. In addition, the concept is highly flexible, where designers can choose from a wide variety of heliostats, receivers and transfer fluids.

The advantages of central receiver are:

1. This system collect the radiation optically and send it to single receiver, therefore minimum thermal-energy transportation required.
2. The concentration ratio varies from 300 to 1500 for collecting solar power and converts it into electricity.
3. It can store thermal energy for some time.
4. It can generate large amount of energy, around 10 MW, i.e. good for economic purposes [11].

Table 1 : Description of CSP Systems [10]

Technology	Temperature (^{0}C)	Hybrid operations	Cost ($/kW)	Efficiency (%)
Parabolic Trough	400	Possible	4156	10-15
Solar Tower	1000	Possible	4500	14-17
Parabolic Dish	750	Under developing phase	6000	18-25

The present paper has therefore the following specific objectives:

- review the CSP technologies and discuss solar power tower advantages compared to the other technologies;
- estimate the hourly beam irradiation flux from available monthly mean global irradiation data for selected locations, and compare the results obtained of monthly data with calculations from the temperatures recorded at the locations;
- select an appropriate plant configuration, and present design preliminary recommendations using predicted hourly beam irradiation

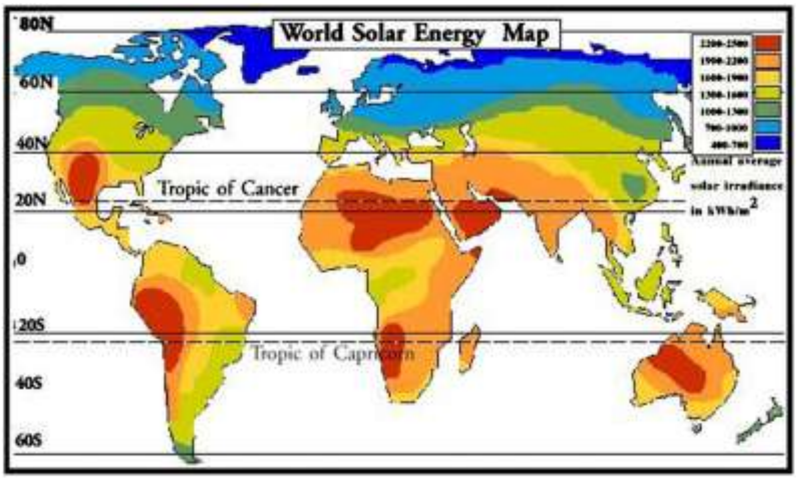

Fig. 1 World solar energy map [8]

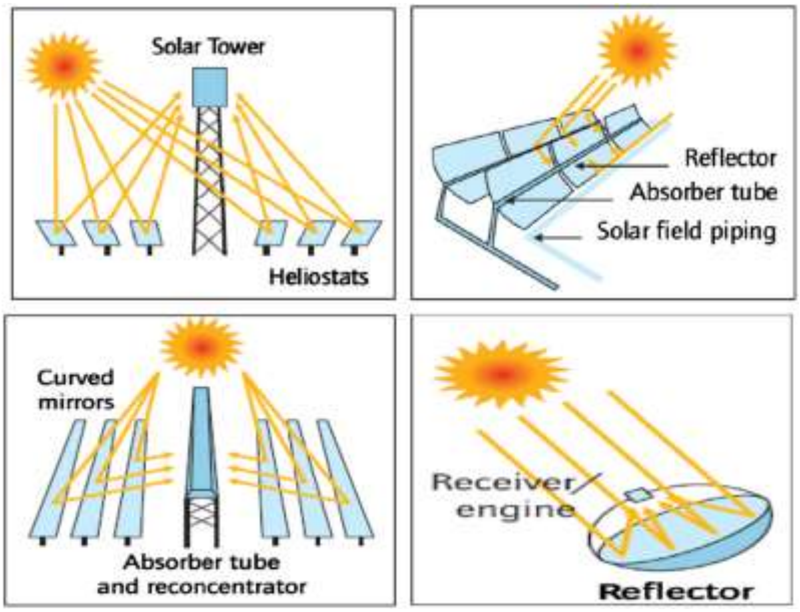

Fig. 2. Currently available CSP technologies (a) STP; (b) PTC; (c) LFR; (d) PDC [7]

Linear Fresnel reflector:

Linear Fresnel reflectors (LFR) approximated in the parabolic shape of the trough systems by using long rows off latters lightly curved mirrors to reflect the sun rays on to a downward facing linear receiver. The receiver is a fixed structure mounted over a tower above and along the linear reflectors.There flectors are mirrors that can follow the sun on a single ordualaxisregime.The main advantage of LFR systems is that their simple design of flexibly bent mirrors and fixed receivers require slower investment costs and facilitates direct steam generation, thereby eliminating the need of heat transfer fluids and heat exchangers. LFR plants are however less efficient than PTC and SPT in converting solar energy to electricity. It is more over more difficult to in corporate storage capacity in to the design. A more recent design, known as compact linear Fresnel reflectors (CLFR) which uses two parallel receivers for each row of mirrors and therefore needs less space than parabolic troughs to produce a given output [14].Linear Fresnel reflector consists of different array of mirrors, which is like Fresnel lens that is used to penetrate light into the receiver situated on a tower. LFR is defined as the pieces of parabolic trough with modification to improve the efficiency and reduce the capital cost. The thermal efficiency varies from 8% to 12%.

III. Enhancing the CSP potential:

As stated before, the CSP potential can been hanced by the in corporation of two technologies in order to improve the competitiveness towards conventional systems: Thermal energy storage (TES)and back up systems (BS). Both systems offer the possibility of a successfully around operation, providing a stable energy supply in response to electricity grid demands [5].

Thermal energy storage systems:

Thermal energy storage systems (TES) apply a simple principle: excess heat collected in the solar field is sent to a heat exchanger and warms the heat transfer fluid (HTF) going from the cold tank to the hot tank. When needed, the heat from the hot tank can be returned to the HTF and sent to the steam generator (Fig. 3). In the vacancy of storage capacity, on the sunniest hours, plant operator interrupt some unneeded solar collectors to avoid overheating the HTF. Storage avoids losing the daytime surplus energy while extending the production after sunset.

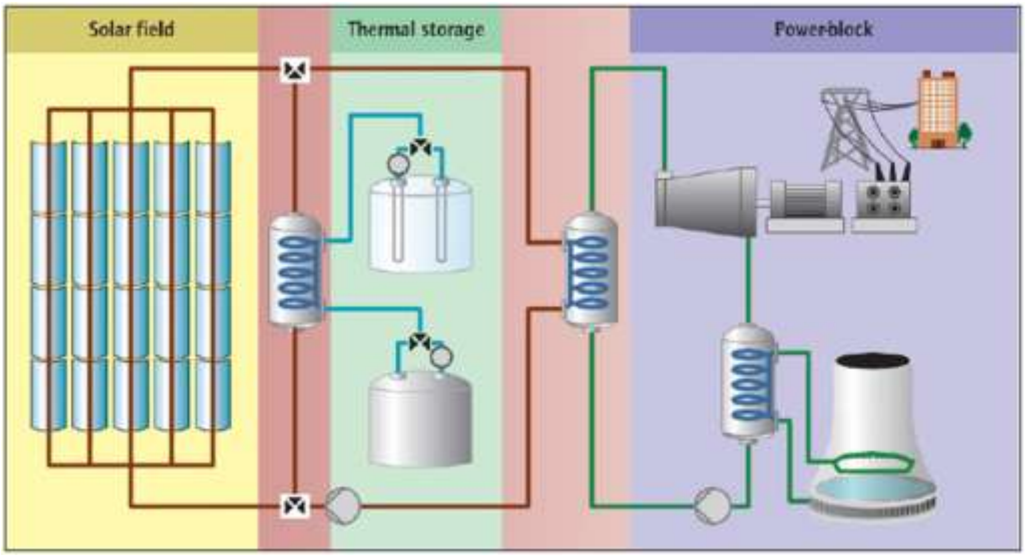

Fig. 3. Thermal energy storage system in a parabolic trough collector plant [7].

Backup systems:

CSP plants, with or without storage, are commonly equipped with a fuel backup system (BS), that help storegulate production with the steam cycle and turbine already in place, only components specific to CSP require additional investment. Atypical performance for a CSP plant enhanced with thermal energy storage system and backup system, in a constant generation at nominal capacity.

IV. Concentrated solar power prospects in India

CSP means large scale conversion of solar energy into electricity with huge investment of capital. However, this technology has potential to produce economical electrical energy with minimum carbon emission in India. These systems are good for the regions where availability of direct sun light and clear sunny days in the year is more [16]. The establishment aim of Jawaharlal Nehru National Solar Mission (JNNSM) by Ministry of New and Renewable Energy (MNRE), Government of India was the first phase to develop solar energy in India, and continuously passes the government norms and incentives regarding this. January 11, 2010 remark as a new age of solar based systems in India. This mission has target to reach 22,000 MW by solar till 2022. In which 20,000 MW was generated by grid connected solar systems and rest of 2000 MW is generated by off grid systems [18]. The whole process is divided into three parts. CSP in India faces few threats, which are discussed in three parts, namely: technical threats, marketing threats and the third one are environmental threats [17]. In India, there are some technical issues which obstruct the expansion of the CSP development. It is also seen that, there is no relevant DNI data are available. Hence, it cannot be estimate properly about the quality and future relevancy of the CSP plant. From several studies it is found that minimum DNI needed for CSP is 5 kWh/m2/day. Secondly, about the marketing threats. The CSP has high capital and operating cost. There is no comparison with PV system, related to cost.

Expenditure of PV system installation is around 5.87 crore per MW, and CSP is 12 crores per MW [20]. Thirdly, about the environmental threats. Water is needed and it is the very basic need of it. It is also required for cleaning mirror and generation of steam. CSP plant has cooling towers to compress water like thermal power plant. International energy agency has found that parabolic trough and linear Fresnel system required water around 3 m3/MWh of electrical energyproduction [19].

Conclusion

To resolve the excellent design and operation of the CSP throughout the year, although defining the required TES and/or BS, an accurate estimation of the absolute daily solar irradiation is needed Results of the model approach is given for 8 selected locations, in both Northern and Southern hemisphere In India, there is a rapid progress in the field of concentrated solar power. India has capacity of 1000 GW for the establishment of the CSP. The Indian government has establishment of JNNSM by MNRE to promote various application of the CSPand others solar applications. Indian government regularly revises the policies to promote the CSP applications.

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