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A review on progress of concentrated solar power in India

Anil Kumar[a,b], Om Prakash[c,*], Akarshi Dube[c]

[a] Energy Technology Research Center, Dept. of Mech. Engg., Faculty of Engineering, Prince of Songkla University, Songkhla 90110, Thailand
[b] Department of Energy (Energy Centre), Maulana Azad National Institute of Technology, Bhopal 462003, India
[c] Department of Mechanical Engineering, Birla Institute of Technology Mesra, Ranchi 835215, India

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ABSTRACT

The electricity generated by concentrated solar power (CSP) in every year is being increased with high rate in India. India have enormous solar power potential for solar electricity generation per watt set up because it has solar radiation of 1700–1900 kW h per kilowatt peak with more than 300 clear sky days in year. Government of India set target of extra solar power generation of 10,000 MW till 2017, and an 100,000 MW till 2022.Therefore, the area of concern in this study is the review of the various installed CSP based electricity generation plant in India.

1. 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 solar radiation 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 and 1691.83 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].

Solar photovoltaic based power generation system has certain serious and noticeable demerits such as low efficiency, large surface etc. These two major problems are being incorporated in the CSP.

CSP systems are involved with different technologies; the parabolic trough technology, the solar tower technology, the dish Stirling system and the linear Fresnel system. Many researchers have examined the capability and application of CSP technology in different sector of the world. Spain, United State and India are the top three country in the world in the application of CSP technology [5]. The geographical information technology has suggested that the CSP technology as parabolic trough collector has huge potential in for South Africa. It has potential of electricity generation up to 547.6 GW. The various result of study states that, CSP system has financial support for north western side of country and it gives around 1800kWh/m^2 which is best suited for the CSP technologies [6]. CSP potential assessment studies shows that this technology has vast prospects in applications of dry riches locations of mid-latitude areas. However, it cannot be applicable in the torrid zones with almost high diffuse fraction of worldwide radiation [2]. Nevertheless, it is no analytical review on this point of question. This is based on weather report. India has also taken up various project to install the CSP technologies in the large scale [7].

From above review, there is plenty of opportunity for CSP development in the India. Hence this review paper will help further reformation of policy, planning and implementation of CSP based power plants in the India. This study would also be helpful in attracting the investors to invest in the development of CSP as distributed power source in remote and non-grid area.

* Corresponding author.
E-mail address: 16omprakash@gmail.com (O. Prakash).

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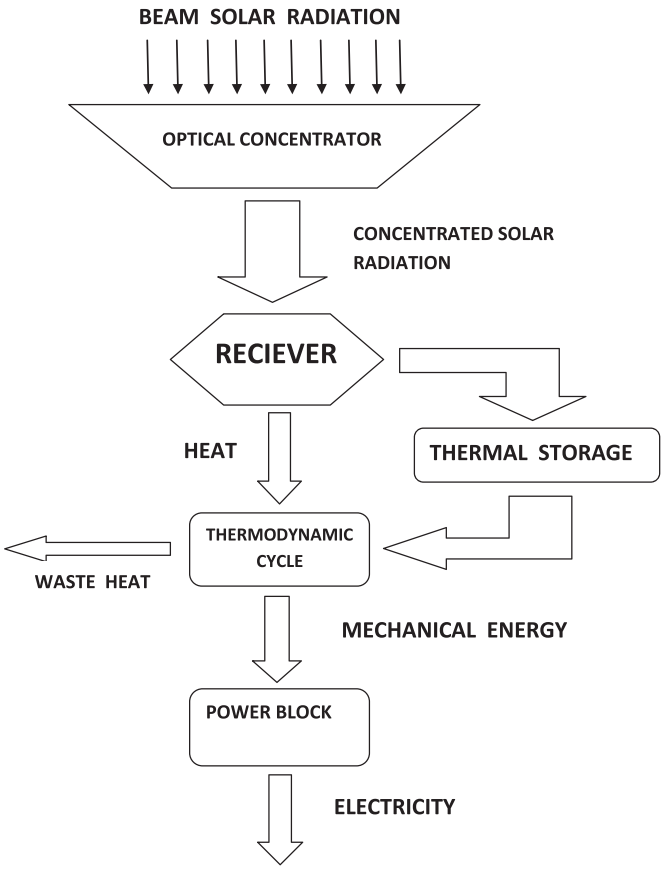

Fig. 1. : Schematic diagram of CSP for parabolic trough Collector [27].

2. Concentrating Solar Power (CSP) technology

The working methodology of CSP for generation of electricity is presented in the Fig. 1. Beam solar radiations are coming to the plate of optical concentrator, these joined together and become concentrated solar radiation, then move to the receiver. Now from this the receiver absorb the thermal energy of the solar radiation and then the absorbed thermal energy is being transferred by the working fluid which run the turbine- generator system. This will lead to the generation of the electricity [8].

Concentrated solar power plant based on: parabolic trough; parabolic dish; solar tower; and linear Fresnel reflectors, all are discussed below one by one. Table 3 represents the performance summary study of different type of CSPs.

2.1. Parabolic trough system

Concentrated solar power can also be divided into two ways namely: line focus and point focus. Parabolic trough collector (PTC) system is working on single axis and has line focus. The complete system consists of: mirror, receiver tube and focal line [9]. The sun rays strike on the mirror, mirrors reflect sun light on black coated metallic tube (absorber) which become 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 [10]. The receiver tube attain 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 [9].

Table 1
Energy demand projections in India [20].

S. No.	Source	Unit	1991–1992	2009–2010	2020–2021
1	Electricity	TWh	231	725	1300
2	Coal	Mt.	229	690	1345
3	Petroleum products	Mt.	57	165	335
4	Natural gas	bcm	18.6	65	130

Table 2
Electricity from CSP plants as shares of total electricity consumption [19].

Countries	Share (%)			
	2020	2030	2040	2050
Australia, Central Asia, Chile, India (Gujarat, Rajasthan), Mexico, Middle East, North Africa, Peru, South Africa, United States (Southwest)	5	12	30	40
United States (remainder)	3	6	15	20
Europe (mostly from imports), Turkey	3	6	10	15
Africa (remainder), Argentina, Brazil, India (remainder)	1	5	8	15
Indonesia (from imports)	0.5	1.5	3	7
China, Russia (from imports)	0.5	1.5	3	4

2.2. 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%. The maximum 1500 °C temperature can be achieved by dish system [10]. 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 [11].

2.3. Solar power tower

Solar power tower also known as heliostat field collector or central receiver based solar collector. These names are given because it is working as point focus or the sun rays striking on the heliostat and move back to the central receiver situated in the middle of the system hence, it can receive the all directed rays reflected by the heliostat mirrors. Mirrors used in this system are slightly concave in shape, maximum amount of energy gets directed into the steam generator to produce steam at high pressure and temperature [12].

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 vary from 300 to 1500 for collecting solar power and convert it into electricity.
3. It can store thermal energy for some time.