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Solar Thermal Technologies for Power Generation in India

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Abstract—*The development of solar thermal power generation has been implemented in various places of this country. Activities are proposed on research, design and development in the area of solar thermal energy with a view to lead deployment and commercialization of technologies for power generation. Research Development and Design activities developed on various components of solar thermal system viz. heliostats, tracking mechanism, tower structure, receiver and storage medium. Various projects are also aimed at to design and development of large area solar dish for application in decentralized solar thermal power generation in kW-range & design and development of Striling engines for power generation.*

1. INTRODUCTION

India is a endowed with a very vast solar energy potential. Most of the part of the country has good Sunshine about 200-250 days, which is available at 4-6.5 kWh/m^2/day of Direct Normal Irradiance (DNI) [1-4]. When incident solar radiation (i.e. DNI, GHI) is captured and transferred as heat, to perform various useful applications, is called solar thermal energy. It is easy for anyone to comprehend the role of heat from solar energy in our daily life and importance of availability of fuel in the future. Depending on the solar thermal technologies, the temperature output of the thermal energy can be achieved up to 3000 ^{0}C. This temperature opens up a vast area of applications like water /air heating, cooking, drying of agricultural & food products and water distillation. Solar architecture for designing of energy efficient building based on the concepts of solar energy is an important emerging application. The current total installed solar thermal power generation capacity in India is 0.5 GW and occupies forth position in the World [5].

2. DIFFERENT SOLAR THERMAL TECHNOLOGIES FOR POWER GENERATIONS

2.1 Parabolic Trough Collector (PTC)

2.2 Linear Fresnel Reflector (LFR)

2.3 Central Solar Tower

2.4 Solar Dish

2.1 Parabolic Trough Collector (PTC) Technology for Power Generation

Parabolic Trough Collector (PTC) basically focuses the sunlight at receiver (line focusing) to achieve higher temperature up to 400 ^{0}C. PTC focuses the direct radiation coming from the sun and need to be tracked [1-axis for E-W & 2-axis for both E-W and N-S] along with the sun. The solar energy received on the collector surface on the 2-axis tracking is greater [6-7] due to the lower incident angle. However the most of the PTC are 1-axis solar tracking, due to the lower cost and ease installation & maintenance. When the PTC orientation axis is N-S, the annual incident energy received on the collector surface is greater, which results in a higher annual collector efficiency and smaller auxiliary energy requirement [8].Depending on their tracking arrangement; these can be put in the category of high temperature applications. The receiver is normally an evacuated tube series which contains heat transfer fluid. Parabolic troughs using thermal oil are the most advanced among all concentrated solar power (CSP) technologies and considered to be the most economical and high temperature solar thermal technology available today. In these tubes heat transfer fluid is circulated, such as synthetic thermal oil. It is heated up to 400 ^{0}C by the concentrated sun's rays, and pumped through a series of heat exchangers to produce superheated steam.

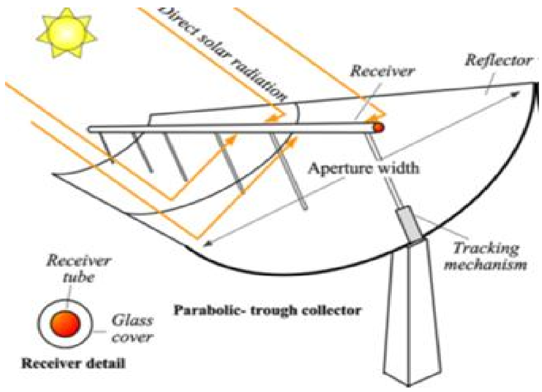

Fig. 2: Schematic of Parabolic Trough Collector

The steam is used to produce electrical energy in a conventional steam turbine power plant. PTC solar technology is the best proven and easy in operation, lowest-cost large scale solar power technology available in India. For other applications like cooling and process heat, some companies have undertaken specific efforts in the development of modular, small, lightweight and low cost PTC.

These developments have allowed a larger number of options of high temperature sources for power generation, fulfilling at the same time basic requirements on costs and maintenance & operation. A 50 MW Parabolic Trough Collectors (PTC) based Solar Thermal Power Plant has been commissioned in Rajasthan [9]. A grid-connected solar thermal power plant, with a capacity of 1 MWe at direct normal iradiance (DNI) radiation of 600 W/m^2, has been designed and commissioned at National Institute of Solar Energy (NISE, formerly solar energy centre), Gurgaon, New Delhi as a part of the project titled 'Development of a Megawatt-scale Solar Thermal Power Testing, Simulation and Research Facility'. The unique feature of the plant is the integration of two different solar fields (parabolic trough collectors and linear Fresnel reflectors) without fossil fuel backup. The plant intends to combine the advantages of synthetic oil based parabolic trough collector (PTC) field and direct steam generation of linear Fresnel reflector (LFR) field.

Fig. 3: MW Solar Thermal Power Plant at National Institute of Solar Energy

The hot oil from PTC field and saturated steam from LFR field are integrated to produce superheated steam at 350°C, 42 bar to run a turbine-generator to produce electricity. It has been designed for generating power for the period of 8 hours in a clear sunny day and having heating storage of the thermic oil for the period of 30 minutes [10]. The power generation of the plant achievedin the month of April and May is 220 MWh/month & 200MWh/monthrespectively as shown in fig.4.

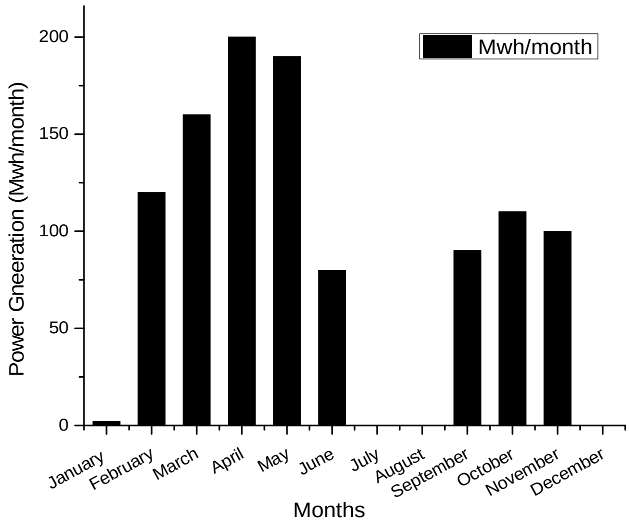

Fig. 4: Monthly Power Generation (MWh/month)

2.2 Linear Fresnel Reflector (LFR) Technology for Power Generation

A Linear Fresnel Reflector (LFR) is a 1-axis tracking technology that focuses sunlight reflected by long heliostats onto a linear receiver to convert solar energy to heat. The classical linear Fresnel system uses an array of mirror strips close to the ground to direct solar radiation to a single, linear, elevated, fixed receiver (Fig.5). The technology is seen as a low cost alternative to trough technology for the production of solar steam for power generation. The main advantages of the Linear Fresnel collector, compared to trough collectors, are seen to low cost [11].

Fig. 5: Linear Fresnel Reflector (LFR)

No need for flexible high pressure joints or thermal expansion bellows due to fixed absorber tube. There is no vacuum technology and no metal-to-glass sealing. The wind loads are substantially reduced on the reflector strips, so the reflector width for one absorber tube can be up to three times the width of parabolic troughs. Due to direct steam generation no heat exchanger is necessary, although trough technology also is evolving to direct steam generation**.** Efficient use of land since the collectors can be placed close to one another.

2.3 Central Tower Technologie for Power Génération

A 2.75 MW of Solar tower power plant has been installed by ACME in Bikaner, Rajasthan. The turbine pressure and temperature are 60 bar at 440 ^{0}C [12]. World largest heliostatwith an area of 150 m^{2}has been installed at Gurgaon with an aim to set up 1 MW$_{th}$ CSP Central Tower Pilot Facility in India [13].

Fig. 6: Central Tower Receiver implemented at NISE

The main objective of this power plant is to (i) development of optimized design of the heliostat field, volumetric air receiver and thermal storage, the three major components of a Concentrated Solar Power (CSP) Central Receiver plant and (ii) development of local sources for all the key components of the plant with a focus on lowering costs, which will make the technology competitive with other forms of energy.

2.4 Solar DishTechnology for Power Generation

Stirling engine for net 1.5 kWe electrical output has been designed at IIT Bombay. It was observed that the engine ran for 11 seconds with electrical heater furnace as the heat source. The maximum speed observed was about 1000 rpm during trial. The efficiency has been achieved in between 30 – 35%. Another solar Stirlingengine has been developed by ONGC with collaboration of INFINIA Company Ltd. USA installed at NISE for performance evaluation test under Indian climatic conditions. This system has 2-axis tracking, i.e. it tracks the sun according to the time of the day and also according to the time of the year. As a result, it always faces towards the sun and concentrates all the direct solar radiation falling on the aperture.

Fig. 7: Dish Concentrators with Stirling Engine

The stirling engine at the receiver point of the dish concentrator is a helium gas engine with 'free piston'.

3. RESULTS AND DISCUSSIONS

Ministry has launched the Jawaharlal Nehru National Solar Mission to achieve 20,000 MW of solar power and its implementation in 3 phases (Phase-I has up to 2012-13, Phase-II is from 2013-2017 and Phase-III will be from 2017-2022) including grid connected solar power. In Phase-I, JNNSM planned a 500 MW grid connected concentrated solar thermal power, whereas 470 MW Concentrated solar power has been allotted for project in 2012-13.The DNI resources analysis results are reliable indication of the solar potential but the use of other DNI sources are slightly difference in results. This analysis is mainly focus on the CSP power plant. The availability of DNI in different states has been analyzed and it shows that, Gujarat and Rajasthan is having highest amount of DNI energy (19.2 and 18.3 MJ/m2/day) in a year as shown in fig. 8.

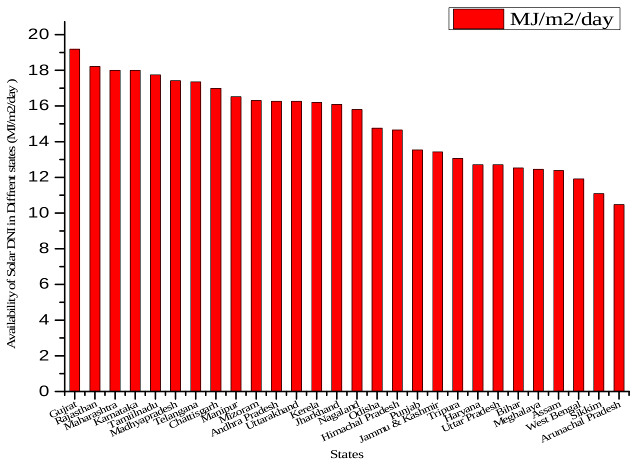

Fig. 8: Availability of yearly average of solar DNI (MJ/m2/day)

The different type of technologies has been used for solar thermal power generation as part of the JNNSM (Phase-II) as shown fig. 9.

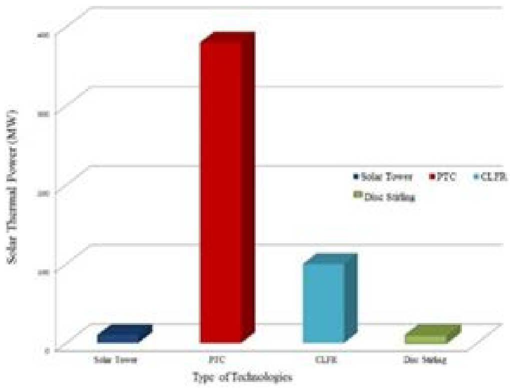

Fig. 9: Installation of Solar Thermal Technologies for Power generation in India

4. CONCLUSION

Taking a view of the trend of accelerated growth of Research & Development and applications of solar thermal technologies in India.Solar thermal power technologies are the most effective technologies to convert solar energy into thermal energy and are considered to be a developed and commercialized technology. However, there exist opportunities to further improve the system performance to increase its reliability and efficiency. The systems have been introduced in the market and are more commonly utilized in the tropical regions of developing countries. Our estimates indicate that, there is a substantial theoretical potential of CO_2 emissions reduction by the use of solar thermal technologies in India. The various benefits that grow by using these systems include saving of conventional fuels, reduction in peak load demand of electricity & emissions of carbon dioxide.

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