Concentrated Solar Power Plant

A Review Paper

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Abstract- **The conventional sources of energy are getting depleting resulting in environmental impacts and so renewable energy production came into existence where the resources are available naturally and in abundant. One of the proven technologies is solar energy generation by solar photovoltaic (PV) and concentrated solar power (CSP). Though it is a renewable source it has failed to make a considerable impact the reason of which are discussed in this paper.**

Keywords:-concentrated solar power plants (CSP), Direct Normal Irradiance (DNI), Capacity Utilization Factor (CUF)

I. INTRODUCTION

Concentrating Solar Thermal Power (CSP) Technology has gained a high level of commercial maturity. Four basic technologies, trough concentrators, tower / heliostat systems, linear Fresnel concentrators and dish concentrators (in declining order of deployment and commercial maturity). A deployment rate has been growing at around 40% per year.

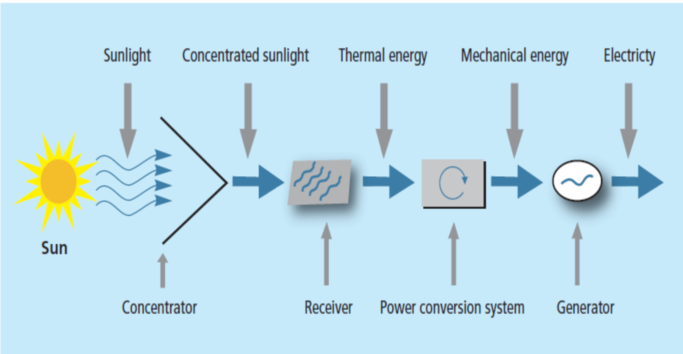

Figure 1: Function of CSP Project

Overall use of solar generation technologies, including photovoltaic systems, is maturing fast and becoming a significant part of the future energy mix. CSP technologies, although only a small part of the present total, have claimed an important place in the future mix, as they offer large scale and proven energy storage as an inherent part of the system [1]. It employs mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat. This heat energy is then used to produce electricity via steam turbine or heat engine that drives the generator. Unlike , photovoltaic cells or flat plate solar collectors, CSP technologies cannot use diffuse part of solar irradiation which result from scattering of direct sun light by various obstacles (clouds, particles, or molecules) in the air, as it cannot be concentrated[2].

II. PRINCIPLE OF OPERATION

Concentrated solar power (CSP) is basically a solar thermal technology. Here the light energy of the sun is concentrated by using reflective mirrors to generate heat, which in turn produces steam to run a turbine. The generator coupled with the turbine rotates and produces electricity. The basic difference between CSP and conventional thermal power station is that CSP uses sunlight as fuel instead of coal or gas to produce steam. Unlike a solar PV system, which can work on direct as well as diffused radiation, CSP can work only with direct radiation. Therefore, the ideal locations for CSP are the Sun Belt regions, i.e. regions between 40 degrees north and south of the equator [3].

III. TECHNOLOGY

There are four main Configurations of CSP that are commercially available – Parabolic Trough, Linear Fresnel, Paraboloidal Dish and Central Receiver Tower [4].

A. Parabolic trough

This technology uses a curved, mirrored trough which reflects the direct solar radiation onto a glass tube containing a fluid (also called a receiver, absorber or collector) running the length of the trough, positioned at the focal point of the reflectors [5]. The collectors track the sun such that its radiation is continuously focused on the receiver. The temperature can rise up to 400 °C [6]. Hot liquid is passed

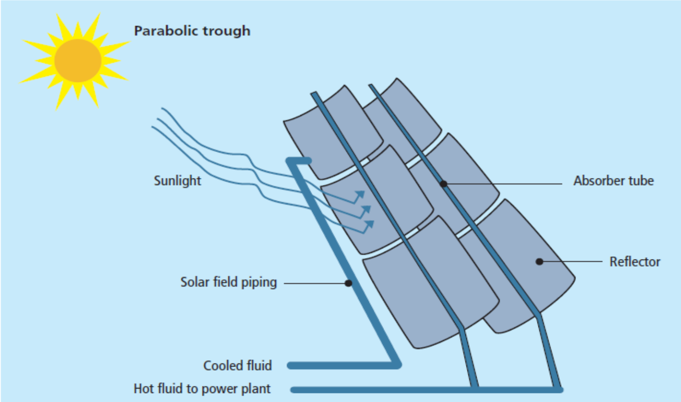

Figure 2: Parabolic Trough Technology

through a series of heat exchangers to generate steam and drive a turbine. Parabolic trough is the most prevalent and proven technology amongst CSP technologies.

B. Central tower receiver

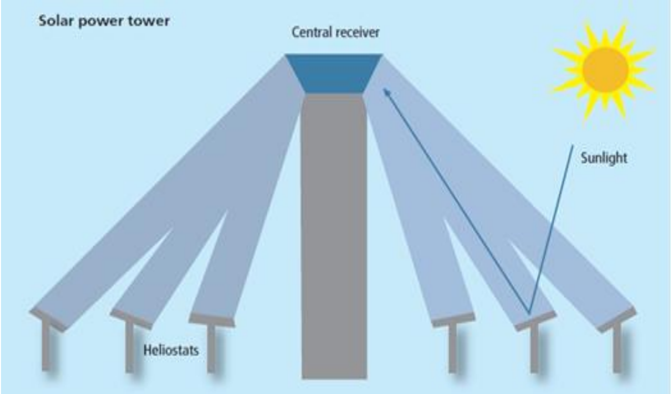

Figure 3: Solar Tower Technology

It is a type of solar furnace employing a tower to receive focused sunlight. A solar furnace uses concentrated solar heat to produce high temperatures. The focused rays heat water and the plant uses the steam produced to drive a turbine. Technologically, power tower has the maximum efficiency because it has the ability to achieve higher temperatures at the collection point when compared to other CSP technologies.

C. Linear Fresnel reflector

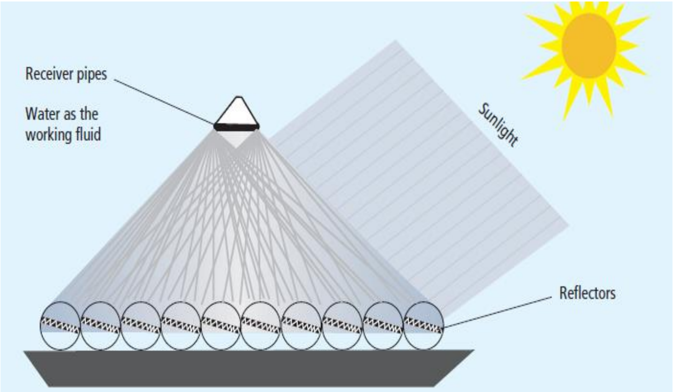

Figure 4: Linear Fresnel Technology

This technology uses long flat mirrors at different angles to reflect sunlight, focusing on one or more pipes. These pipes have heat-collecting fluid mounted above these angled mirrors. The relative simplicity of this CSP technology makes it comparatively cheap to manufacture. When compared to other CSP technologies, Fresnel uses lesser equipment. The biggest advantage of Fresnel plants is that it requires lesser area to operate in comparison to other technologies for the same power output.

D. Dish sterling engine

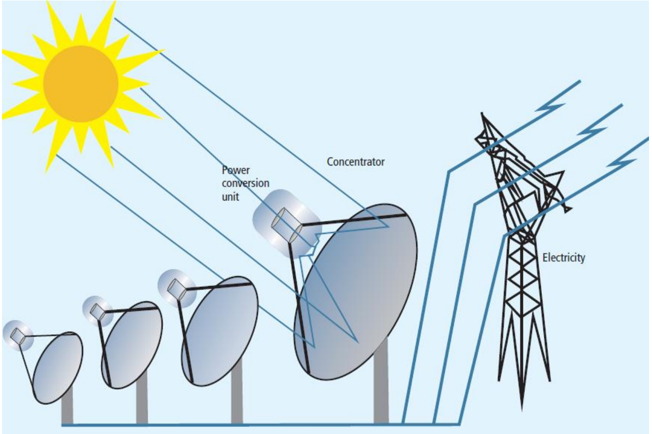

Figure 5: Dish Sterling Technology

A solar dish system uses a dish-shaped concentrator (like a satellite dish) that reflects solar radiation onto a receiver mounted at the focal point. The receiver can be a Stirling engine and generator (dish/engine systems) or it may be a type of photovoltaic panel that has been specially designed to withstand high temperatures (CPV systems). [11]The receiver can be a Stirling engine and generator.

IV. CASE STUDY

A. Ashalim Power Station, Israel

Country:	Israel
Project:	Ashalim
User:	Megalim Solar Power Ltd. (End user: Israeli Electric Corporation)
Scope:	EPC turnkey solar thermal power plant and solar power tower Bright Source: Solar field
Electrical output	121 MW
Commercial operation	2017

Table 1: Ashalim Power Station, Israel

Project Highlights

This plant produces 320 GWh of power per year. It load is approximately 120,000 homes. The Solar Thermal Power Station, located in Israel's Negev desert. It is also the first solar thermal or concentrated solar power (CSP) plant to be undertaken in Israel [7].

Harnessing the Sun

This power station's concentrated solar power (CSP) technology will use 55,000 computer-controlled heliostats or mirrors spread over a 3.15 km2 area to track the sun in dual axes. The sunlight will be reflected to a Solar Receiver Steam Generator (SRSG), located at the top of a 240-meter tower. When the concentrated sunlight strikes the SRSG, it heats water in the boiler to generate superheated steam which is fed to a steam turbine for power generation. Compared to solar photovoltaic (PV) applications, direct steam CSP has the advantage of being able to produce electricity for longer duration of time during the solar hours. The ability to operate during peak demand times reduces the need for utilities to build power plants to operate only during peak times – thereby lowering the overall system's electricity production costs.

Environmental and Social Benefits

This plant will help increase Israel's energy security by reducing dependence on fossil fuel imports. At the same time, it will avoid 110,000 tons per year of CO2 emissions, thus having 10% dependence on renewables in next decade. Locally, the plant could create jobs in a remote area during construction, also creating jobs opportunity in long run

Innovative Solution

Its load generation profile allows this plant to generate power in a more stable and grid-friendly way than comparable PV installations that fluctuate their output more rapidly depending on cloud conditions.

Power rating	121 MW
Power rating (normal operation)	110 MW
Fuel	Solar + gas
Power from gas	Max.: 15% (in one year)/50% (in one day)
Power tower height	240 m
Solar field area	3.15 km^2
Number of heliostats	55,000

Table 2: Technical Specifications

B. 3,780-MW hybrid combined cycle natural gas and parabolic trough concentrating

Solar power (CSP) generation in Florida, USA added 75 MW of parabolic trough CSP to its 3,705–MW combined cycle natural gas, making it the world's largest such hybrid power plant [8]. This project merges solar thermal into a gas-turbine cycle without the need for heat exchangers [9].The hybridization of gas turbines with concentrated solar energy has been underdeveloped for many decades.

The plus point of hybrid power plants is that they produce electricity at the most competitive rates, emit the least carbon dioxide and consume the least possible water.

The hybrid plant has a field of 190,000 parabolic mirrors that heat up a synthetic oil thermal fluid as a heat transfer fluid to 398°C.[10] Even before the addition of the solar generation component, the 3,705-MW Martin County power plant was the US's largest fossil-fuelled power plant. The CSP project is a retrofitted addition to an existing fossil-fuel generation plant in an area of 500 acres because of which the costs on new turbines, transmission lines and other generation infrastructure were saved. The FPL claimed that this retrofit saved 20% of the total expenditure on this project

C. Godavari green energy limited

The plant has been operating for a year with a Siemens turbine of a rated capacity of 55 MW. [11] During April 8-10, 2014, the plant was using 47 per cent of its capacity after 10-12 hours of operation. In May 2014, the plant achieved a CUF of 29 per cent, the highest recorded so far for the plant. The minimum generation has been zero in July 1-4, 2014, mostly on account of cloudy days. From January onwards, the CUF of the plant has been 24 per cent.

Technology:	Parabolic trough
Status:	Operational
Country:	India
City:	Nokha
Region:	Rajasthan
Lat/Long Location:	27°36′ 5.0″ North, 72°13′ 26.0″ East
Land Area:	150 hectares
Electricity Generation:	118,000 MWh/yr (Estimated)
PPA/Tariff Rate:	12.2 Rs per kWh
PPA/Tariff Period:	25 years
Project Type:	Commercial

Table 3: Background

Plant Configuration

Solar-Field Aperture Area:	392,400 m²
No.of Solar Collector Assemblies (SCAs):	480
No. of Loops:	120
SCA Aperture Area:	817 m²
Solar-Field Inlet Temp:	293°C
Solar-Field Outlet Temp:	390°C

Table 4: Solar Field

Turbine Capacity (Gross):	50.0 MW
Turbine Capacity :	50.0 MW
Turbine Manufacturer:	Siemens
Cooling Method:	Wet cooling

Table 5: Power Block

V. CHALLENGES

A. Cost and T&D Losses: Adding to the cost are T&D losses that are approximately 40 %, make generation through solar energy sources highly unfeasible. The government has tied up with world-renowned universities to lower the installation cost of solar power sources and is focusing research and upgrades required, of substations and T&D lines to reduce T&D losses [12].

B. *No reliable Direct Natural Interference (DNI) data*: Knowledge of the quality of solar irradiance at a particular location and future reliability and hence availability of the resources can't be estimated. Thus accurate estimation of performance is affected [13].

C. *Land Scarcity*: Per capita land available with minimum required DNI is very low in India. Thus, land is a scarce resource.

D. Funding of initiatives like National Solar Mission is a constraint as far as India's inadequate financing capabilities are concerned.

E. *High cost*: Manufacturers are mostly focused on export markets that buy various solar technologies at inflated prices thereby increasing their profits. [14]

F. *No skilled Manpower* Training and development of human resources to drive industrial growth and PV adoption.

G. *Land allotment & Power Purchase Agreement* signing is a long procedure under the Generation Based Incentive scheme.

VI. CONCLUSION

CSP has significant cost reduction potential – immediately and with future innovative developments. CSP has strong growth potential in many countries – mainly those with high irradiation in the world‘s sun belt. As technologies and market participants develop, dynamics towards lower prices will increase in the industry. The challenges faced by CSP technology can be overcome in the future with considerable investment in the research and development to increase the CUF. Having the added advantage of having a storage capacity it is likely to replace the conventional thermal in near future.

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