International Journal of Scientific Research & Engineering Trends
Volume 7, Issue 4, July-Aug-2021, ISSN (Online): 2395-566X

Concentrated Solar Power

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***Abstract*- Integration technology has become important due to the world's energy requirements which imposed significant need for different methods by which energy can be produced or integrated, in addition to the fact that integration of solar energy into non-renewable sources is important as it reduces the rates of consuming of non-renewable resources hence reduce dependence of fossil fuels. Basically, there are two types of solar power generation used in integration with grid power - concentrated solar power (CSP) and photovoltaic (PV) power. CSP generation, sometimes known as solar thermal power generation, is much like conventional thermal power generation that converts thermal energy (steam) into electricity.The direct current is then converted to alternating current, usually using inverters and other components, in order to be distributed onto the power grid network.**

***Keywords*- concentrated solar power , photovoltaic , integration of solar energy etc.**

I. INTRODUCTION

Concentrated solar power (CSP, also known as concentrating solar power, concentrated solar thermal) systems generate solar power by using mirrors or lenses to concentrate a large area of sunlight onto a receiver.

Electricity is generated when the concentrated light is converted to heat (solar thermal energy), which drives a heat engine (usually a steam turbine) connected to an electrical power generator or powers a thermochemical reaction.

Fig 1. Concentrating Solar Power technology.

Concentrating Solar Power (CSP) is a promising technology for power generation in which the solar radiation is concentrated to generate high temperature for producing steam in a solar thermal power plant. No fossil fuel is used in this technology; therefore no greenhouse gases are emitted. [10] CSP had a global total installed capacity of 5,500 MW in 2018, up from 354 MW in 2005. Spain accounted for almost half of the world's capacity, at 2,300 MW, despite no new capacity entering commercial operation in the country since 2013.[8]

The United States follows with 1,740 MW. Interest is also notable in North Africa and the Middle East, as well as India and China. Among the larger CSP projects are the Ivanpah Solar Power Facility (392 MW) in the United States, which uses solar power tower technology without thermal energy storage.

II. CURRENT TECHNOLOGY

Concentrated-solar technology use mirrors or lenses with tracking systems to focus a large area of sunlight onto a small area. The concentrated light is then used as heat or as a heat source for a conventional power plant (solar thermoelectricity). The solar concentrators used in CSP systems can often also be used to provide industrial process heating or cooling, such as in solar air conditioning.

In concentrating solar power (CSP) technology sun's Direct Normal Irradiation (DNI) is concentrated to produce heat of temperature 400ºC to 1,000ºC .This heat is used to produce electricity by conventional steam cycle, or combined cycle, or Stirling engine.

1. Overview of CSP technology:
In CSP power plants, electrical energy is generated by concentrating solar radiation. Generally, CSP plants consist of several components such as solar concentrators, receiver, steam turbine and electrical generator. Until today, four different kinds of CSP power generation plants are found; [9]

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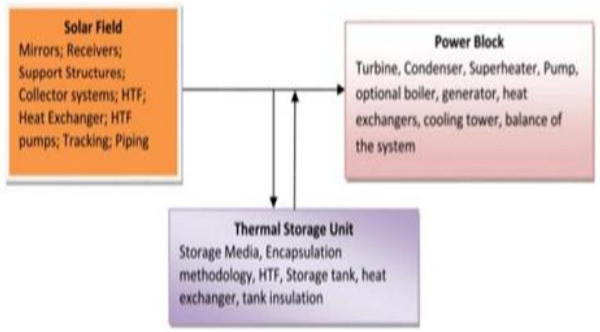

Fig 2. Main parts of a CSP plant and their components. [2]

Based on the process of collecting and concentrating solar radiation, the CSP can be categorized into four major technologies: [9]

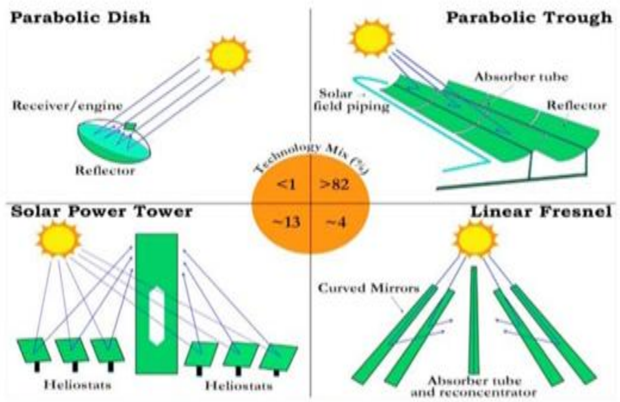

Fig 3. Various CSP Technologies along with their installed Ratio.

- Parabolic Trough
- Solar Tower or Central Receiver,
- Parabolic Dish and
- Linear Fresnel Reflector (LFR).

1.1 Parabolic Trough:
This technology uses parabolic trough shaped mirrors to concentrate the incident DNI onto a receiver tube which is placed at the focal line of the trough. [10]

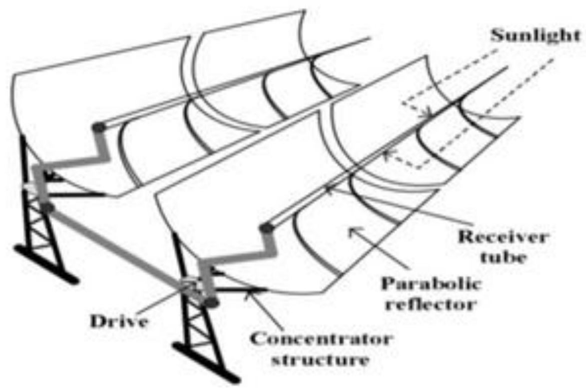

Fig 4. Solar collector assembly.

The reflector is composed of a 0.85mm thick silver coated mirror on the back layer and a 4mm glass of high transmittance on top of it, acquiring the overall reflectivity of about 93.5%. A stainless steel tube of 70mm diameter with high heat absorption coating encircled by a vacuum glass tube of 115mm diameter with antireflective coating comprise the receiver tube . The tube circulates a heat transfer fluid (HTF), such as: synthetic thermal oil, which is heated up to 400ºC by the concentrated solar energy. [10]

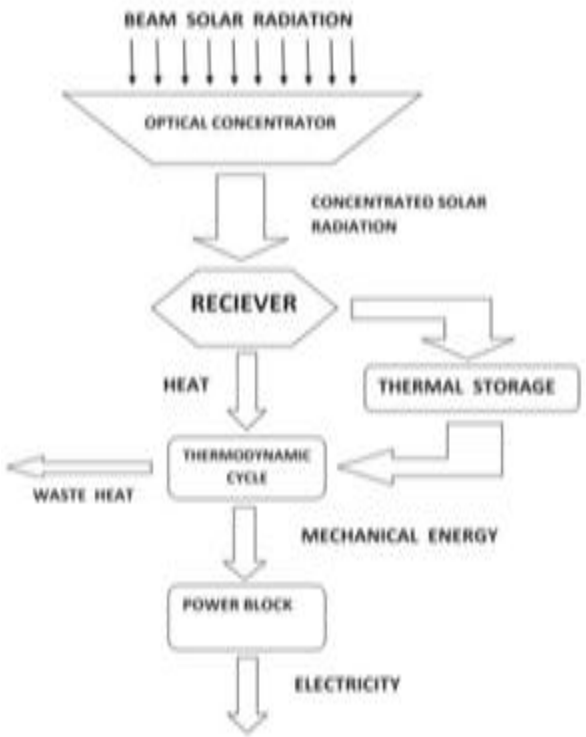

Fig 5. Schematic diagram of CSP for parabolic trough [2] Collector. [3]

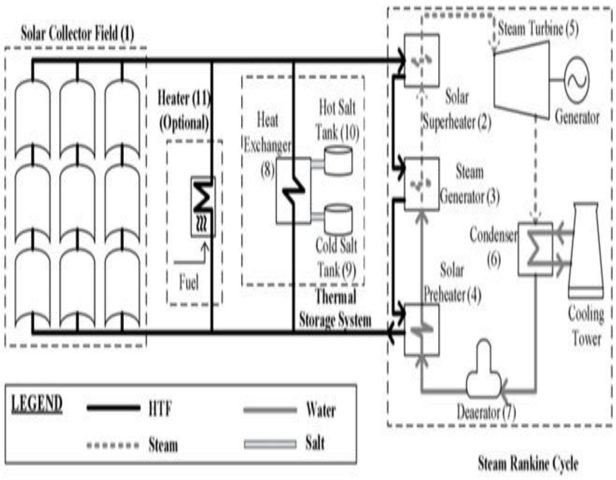

Fig 6. Parabolic trough power plant with steam Rankine cycle and thermal storage. [3]

In order to collect the DNI effectively, each SCA is equipped with a local control system which automatically rotates the concentrator structure using a drive motor to track the sun from dawn to dusk. Numerous SCAs aligned in parallel rows on north-south axis create the solar collector field (SCF) of the parabolic trough power plant. [10]

During sunny days the HTF in the receiver tube heated by the concentrated solar energy is circulated to the steam power plant where the HTF preheats the water, generates steam in the steam generator and also superheats the steam. After discharging heat in the power plant the cooled HTF is circulated back to the SCF to get heated again thereby completing the cycle. To continue electricity generation at night or in cloudy days the system can be equipped with the optional storage system. [10]

During daytime a portion of the heated HTF is diverted to the heat exchanger. Cold molten salt pumped from the cold tank receives thermal energy from the HTF in the heat exchanger and is stored in the hot tank. At night or in cloudy days the above mentioned storage cycle is reversed; the hot molten salt returns its thermal energy to the cold HTF which is then used to produce steam. [10]

1.2 Solar Tower or Central Receiver:
The main difference between parabolic trough and solar tower technology is the way heat is accumulated from the sun. In the solar tower technology, the SCF contains a radial arrangement of several individual computer controlled sun tracking large mirrors (named as heliostat) that concentrate the solar energy onto the receiver placed on top of a central tower.

The HTF (usually molten nitrate salt) is heated up to approximately 1,000ºC in the receiver. The rest of the procedure of electricity generation is almost same as that of parabolic trough technology. [10]

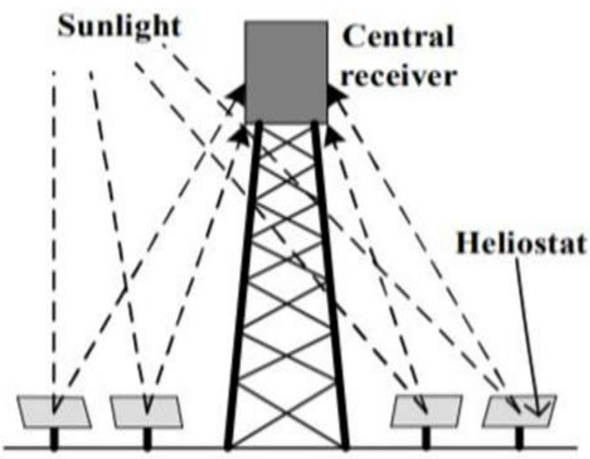

Fig 7. Solar Tower or Central Receiver. [3]

1.3 Parabolic Dish:
This technology uses a parabolic dish-shaped solar concentrator that concentrates the sunlight onto a receiver (solar heat exchanger) placed at the focal point of the dish.

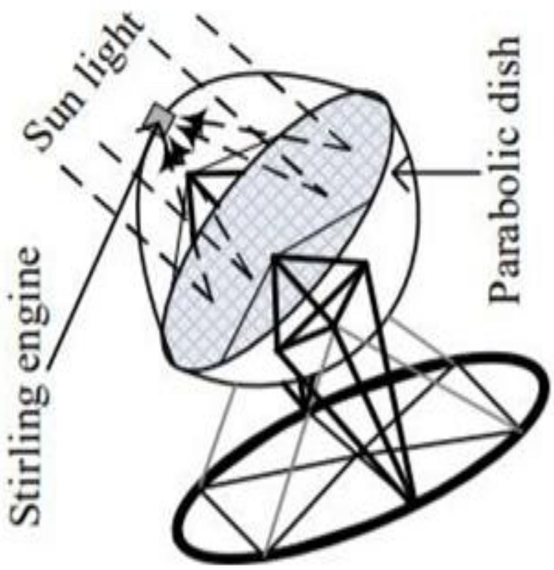

Fig 8. Parabolic Dish.

The dish usually tracks the sun in two axes (azimuth and elevation) with the help of a tracking system. The heat generated in the receiver is used to drive a Stirling engine that is attached to the receiver.

The working gas of the Stirling engine is hydrogen or helium which is heated up to 750ºC. The mechanical energy produced by the engine is converted to electrical energy by an alternator. A parabolic dish of 25kWe output requires a diameter of 37 feet. [10]

1.4 Linear Fresnel Reflector:
LFR-CSP plants consist of an array of linear mirror strips as reflectors, with receivers, tracking system, process and instrumentation system, steam turbine and generator. The reflectors are the most important components in the system and the mechanism of the reflectors is the same as that of the Fresnel lens. [9]

The sun's rays are reflected by the Fresnel lens and focused at one point, generally on to a permanent receiver on a linear tower. In the daytime, the Fresnel reflectors are directed automatically toward the sun, and from there the reflected solar irradiation carries on to the linear tower where a receiver shaped like a long cylinder contains a number of tubes filled with water. [9]

A LFR is made up of a number of linear mirror strips. This type of reflector can also resemble the dismantled reflector of a parabolic-trough system. Using Fresnel reflector design, the capital cost of the reflectors becomes lower, however the efficiency is less than with parabolic-trough reflectors. [9]

In 2014, the largest operational linear Fresnel-reflector CSP plant was installed in India, with a capacity of 125 MW and a planned electricity generation of 280,000 MW h/year.

Fig 9. 10 MW PS-10 solar power towers at Seville, Spain.[2]

2. Comparison of CSP Technologies:

All the CSP technologies have the key advantage of generating clean energy with no fuel cost; but the huge land requirement is their main drawback. The SEGS (Solar Energy Generating Systems) plants in Mojave Desert, California occupy 6.5 km2 of land area to produce 354 MWe (17,000m2 per MWe).

But the land use requirements for CSP plants are in fact less than hydroelectric plants or coal plants if the size of the artificial lake or the land required for mining and excavation of the coal are taken into account. [10]

Table 1. Different CSP Technologies.

Technology	Focus	HTF [3]	Temperature [3]	Hybrid Operation	Cost ($/KWe)	World Capacity, MWe [8]		
						Operational	Under construction	Announced
Parabolic Trough	Line	Synthetic oil	400°C	Possible	4,156♠	570	1550+140 ISCC	5775.1
Solar Tower	Point	Molten salt	1,000°C	Possible	4,500♣	34	22	1514
Parabolic Dish	Point	N/A	750°C	Still in R&D phase	6,000 [11]	0.5 [3]		1600.08
Linear Fresnel	Line	Steam	270°C [9]	Possible	2,200 [12]	8.4		487

3. Status of CSP Projects:

It was identified that, even though the first CSP plant was installed in the USA in 1982, this technology is expanding rapidly worldwide and, as a result, there are currently 98 active CSP plants, while 18 are under construction and 24 plants are under development. [9]

Table 2. Number of CSP Plants in the world.

Type of CSP plants	Operational	Under construction	Under development
PTCs	77	10	10
SPT	13	6	10
SPDes	1	0	0
LFRs	7	2	4
Total	98	18	24

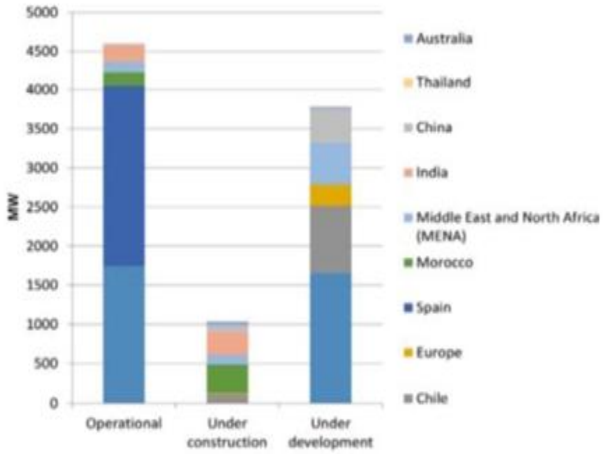

Fig 10. Total Capacity of the Operational, Under Construction and Under Development CSP Plants.

CSP technology is expected to grow rapidly all over the world, especially in Asia, the MENA and South American countries. Daily solar availability, sufficient land area and a source of water for cooling and cleaning of the reflectors are crucial for the development of CSP plants.

A range of costs including capital cost, basic cost and operation and maintenance cost, efficiencies, land and water requirements, and others are compared. [9] For all the technologies, the solar radiation, land and water requirement was found to be 1800 kW h/m2 , 5–7 acres/MW and 4 m3 /MW h, respectively. [9]

However, from installed CSP plant experience, it is found that SPTs require the largest area. But again the area depends on the presence of heat storage facilities. If heat storage is not being considered, the land area requirement will be 25 m2/kW for the PTC and 45 m2 /kW for the SPT. However, parabolic-trough technology is the most proven, SPT is mature, and both SPDes and LFRs are in the demonstration stage.

Unlike the low capacity, SPDes have the highest concentration ratio, ranging from 1000 to 3000, one of the highest among all other CSP technologies. SPTs and SPDes are regarded as the most efficient CSP plants, expected to have a 50% better efficiency than the trough and the Fresnel plants. Even though SPDes have the highest efficiency, the basic plant cost, the operation and maintenance cost, and the capital costs are the highest among the plants, with the LFR being the lowest. [9]

4. Global Prospects of CSP Technology:

As coming to the 21st century, the world has to meet the challenges of global climate change and the high crude oil consumption rate. Crude oil gives 40–43% of world's energy. The 40% of global warming is only because of fossil fuels (coal and oil). CSP is one of the new tool in non-conventional energy systems i.e. perceive to be the major part of electricity generation in near future. [11] This system is clean, relevant, and eco-friendly.

The entire world should have focus on the establishment of the CSP plant. This is mainly because CSP is one of high credential system for producing electricity as compare to solar photovoltaic (PV) or renewable energy. In various tropical arenas, fogs minimize the annual generation of CSP plants to certain a range that it possibly will never become reasonable. Due to this difficulty, this is complicated for the countries situated to the equatorial arena to explore their individual CSP plant. [11]

5. Concentrated Solar Power Prospects in India:
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. CSP in India faces few threats, which are discussed in three parts, namely: technical threats, marketing threats and the third one are environmental threats. [11]
In India, there is some technical issues which obstruct the expansion of the CSP development. From several studies it is found that minimum DNI needed for CSP is 5 kWh/m2 /day. [11]

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. [11]

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 fond that parabolic trough and linear Fresnel system required water around 3 m3 /MWh of electrical energy production. [11]

6. Challenges for CSP:
CSP plants are already operating on a large scale in many locations around the world. However, currently CSP offers moderate conversion efficiencies and uncompetitive costs, and therefore requires significant government incentives. [13] Reducing component and plant costs by developing improved materials, manufacturing practices and adding thermal storage to provide true dispatch ability. Many opportunities are available for improving CSP: increasing The operating temperature, which in turn would increase the conversion efficiency and reduce specific costs (per unit energy). [13] These improvements require major advances in materials, thermodynamics, heat transfer, and other disciplines, as well as further development and demonstration.

It is expected that improved CSP technologies will reach grid parity around 2025, leading to a better competitive position in the market and to implementation on a much larger scale. [13]

7. Advantages:
- Renewable source of clean, natural energy, with no external fuels required
- Non-polluting in its operation, and carbon-free except for emissions produced during manufacture and transportation of the components
- Low operating costs. [14]
- High efficiency, including the ability to use thermal storage to store energy outside of daylight hours and therefore better optimize supply with demand patterns
- Scalable to the 100MW+ level. [14]

8. Disadvantages:
- Dependent on plentiful direct sunlight (as with all solar energy generation)
- Typically high construction and installation costs
- Installations require a considerable amount of available land (usually, fairly remote land), therefore, availability of suitable locations is a major factor.

9. Application of power electronics in concentrated solar power
- Water heating,
- Space heating,
- Solar air conditioning,
- Refrigeration,
- Solar power plant,
- Pumping irrigation water,
- Desalination,
- Industrial process heat (IHP),
- Thermal power systems,
- Solar furnaces,
- Solar chemistry,
- Generation of clean electricity,
- Steam generation,
- Selective coatings,
- Study of materials for high temperature applications,
- Solar processing of materials,
- Solar air turbine,
- Solar fuels,
- Solar cookers,
- Solar driers,
- Solar chimneys,
- Solar stove,

- Solar lighting,
- Solar pumped laser,
- Solar cars,
- Solar green houses and
- Solar reactors.

III. LITERATURE SURVEY

The purpose of this study is to identify the availability of alternative energy formulas related to concentrating solar collectors. The literature results are shown in the outline of the principle framework to allow an overall analysis of renewable energy systems and to determine possible future directions for research throughout the region.

The investigation of the theoretical performance of a Concentrating Solar Thermal Electric System (CSTES) by using a field of Parabolic Trough Collectors (PTC) was performed by **Yasemin USTA, 2010.** The potential of using the CSP and the strategy to promote the development of this technology in Turkey to decreasing the demand load, **at 2011 by Kamil Kaygusuz.**

Miqdam Tariq Chaichan, et al, 2012, focused on the feasibility of improving efficiency of the Concentrating Solar Power (CSP) plant, by manufacturing a diminished prototype.

Esmail M.A. Mokheimer et al. [19], 2013, studied the evaluation of the average hourly, daily, monthly and annually thermal efficiency of the Parabolic Trough Collectors (PTCs).

A steam generation by utilizing the solar energy by using a concentrated solar dish was investigated by **Ghanim Kadhim Abdul Sada, Adrien Emad Saad-Alden, [21], 2015.**

IV. CONCLUSION

Electricity production from conventional energy sources creates several bottlenecks such as the risk of a sudden drop in supply quantity, emission of major GHGs like CO2, and a threat to overall environmental sustainability. On the other hand, renewable-energy sources provide abundant, clean and sustainable energy that will clearly be at the forefront in terms of delivering an inexhaustible supply of energy.

Among the four different types of CSP technologies, the parabolic trough collector (PTC) and the solar power tower (SPT) are the two popular technologies that are currently installed in many countries, such as Spain, USA, China, and India.A Research and publications on CSP is expanding at a tremendous pace. With VOSviewer text-mining software, a bibliometric analysis on CSP research was performed and the scientific landscape of the most widely researched, newly emerging topics and the most influential articles were identified and reviewed. 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. Various CSP plants are working successfully.

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