CONCENTRATED SOLAR POWER PLANT

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Abstract – *Concentrating solar power is electricity generated from mirrors to focus sunlight on to receiver that captures the sun's energy and converts it into heat that can run a standard turbine generator or engine. CSP system range from remote power systems as small as a few kilowatts up to grid-connected power plants of 100's of megawatts. CSP produces electricity by concentrating the sun's rays to heat a liquid, solid or gas that is then used in a downstream process to generate electricity. A CSP plant consists of a solar concentrator system made of a receiver and collector to produce heat, and a power block.*

***Keywords* : Electricity , heliostate , reflector , heat transfer , solar heating , fluids , batteries.**

1. INTRODUCTION

Concentrating solar power (CSP) technologies use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat. Power generated by using different methods in CSP plant. This thermal energy can then be used to produce electricity via steam turbine or heat engine that drives the generator. The sunlight hits the earth's surface both directly and indirectly, through numerous reflections and deviations in the atmosphere. On clear days, the direct irradiance represents 80 to 90 % of solar energy reaching the earth's surface. On a cloudy or foggy day, the direct component is essentially zero. Unlike , photovoltaic cells or flat plate solar collectors, CSP power plant cannot use diffuse part of solar irradiation which result from scattering of direct sun light by clouds, particles, or molecules in the air, because it cannot be concentrated. However, one of the key benefits of choosing CSP over PV is be that CSP plants can more easily provide ancillary services and provide dispatch able power on-demand using long-term storage.

In 2005, Concentrated Solar Power generated a mere 0.025% of global electricity. However, the concentrated solar power energy sector is growing quickly.

1.1 WHY CONCENTRATED SOLAR POER IS USED?

Concentrating solar power (**CSP**) plants use mirrors to concentrate the energy from the sun to drive traditional steam turbines or engines that create electricity. The thermal energy concentrated in a **CSP** plant can be stored and **used** to produce electricity when it is needed, day or night. For large-scale CSP plants, the concentration is most commonly by reflection by mirrors, rather than by refraction with lenses.
The sun's rays are concentrated either to a line (linear focus, as in trough or linear Fresnel systems) or to a point (point focus, as in central receiver or dish systems). With photovoltaic energy prices dropping and concentrated solar power (CSP) towers operating at higher temperatures. There are four main utility scale CSP designs currently in use: parabolic troughs, tower systems, linear troughs and parabolic dishes.

Over 90% of the generation capacity in installed CSP is in parabolic troughs, but many in the solar industry speculate that tower systems will become more widely used in the future.Within the United States, CSP plants have been operating reliably for more than 15 years. , the use of salts in CSP trough plants is being investigated to lower operating costs. All CSP technological approaches require large areas for solar radiation collection when used to produce electricity at commercial scale.CSP technology utilizes three alternative technological approaches: trough systems, power tower systems, and dish/engine systems.

1.2 CSP v/s P.V.

When discussing CSP one should consider more than just the power towers, as there are only a few that are in operation. More common are parabolic trough solar thermal power plants, which are less harmful to birds. Parabolic trough systems are often applied in hybrid systems paired with conventional power plants. The conventional part of the plant provides power throughout the night, and the solar energy is added to the total capacity during the day.

But when it comes to producing electricity from the sun, solar PV panels are also contributing in PV power plants. The debate of whether CSP or PV power plants will prevail has been argued for several years. When looking at current and future price levels CSP has—and will have—the highest levelized cost of electricity (LCOE; €/kWh). Due to large price reductions in PV over the last few years the LCOE of PV is about half the cost of CSP, and will remain so until 2030.

Unlike PV—besides pricing—CSP faces many other challenges focused around water for cooling CSP; the speed at which a PV plant can be built compared to CSP; and PV's proven technology. When it comes to financing, these factors may push investors more towards PV than to CSP.

However, one of the key benefits of choosing CSP over PV is be that CSP plants can more easily provide ancillary services and provide dispatch able power on-demand using long-term storage. Combining these features in a hybrid power plant could make CSP competitive with PV in the future.

2. Technologies of CSP

Power generated by using different methods in CSP plant.

2.1 Parabolic trough collector

A parabolic trough is a type of solar thermal collector that is straight in one dimension and curved as a parabola in the other two, lined with a polished metal mirror.

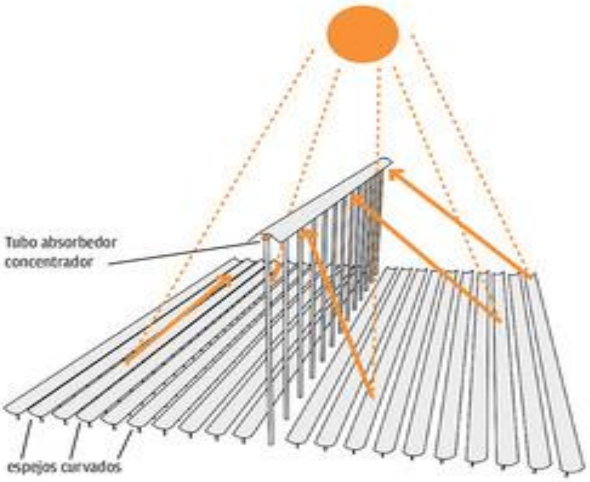
[Fig. 1 Parabolic trough concentrating solarcollector]

The energy of sunlight which enters the mirror parallel to its plane of symmetry is focused along the focal line, where objects are positioned that are intended to be heated. For example, food may be placed at the focal line of a trough, which causes the food to be cooked when the trough is aimed so the Sun is in its plane of symmetry. Further information on the use of parabolic troughs for cooking can be found in the article about solar cookers.

For other purposes, there is often a tube, frequently a Dewar tube, which runs the length of the trough at its focal line. The mirror is oriented so that sunlight which it reflects is concentrated on the tube, which contains a fluid which is heated to a high temperature by the energy of the sunlight. The hot fluid can be used for many purposes. Often, it is piped to a heat engine, which uses the heat energy to drive machinery or to generate electricity. This solar energy collector is the most common and best known type of parabolic trough. The paragraphs below therefore concentrate on this type.

2.2 Linear Fresnel collector technologies

Linear concentrating collector fields consist of a large number of collectors in parallel rows that are typically aligned in a north-south orientation to maximize annual and summer energy collection. With a single-axis sun-tracking system, this configuration enables the mirrors to track the sun from east to west during the day, which ensures that the sun reflects continuously onto the receiver tubes.

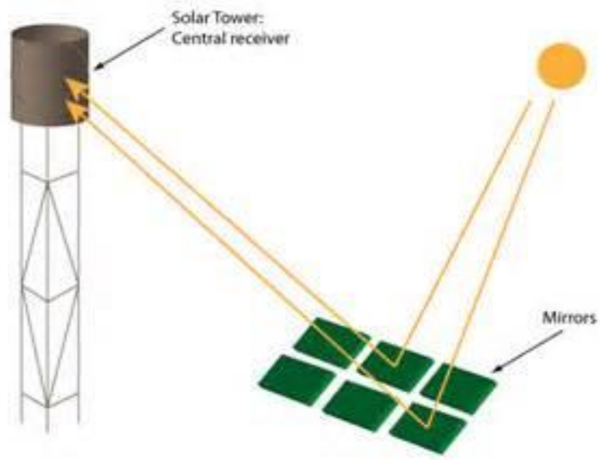


[Fig. 2 Linear Fresnel collector technologies]

Linear systems may incorporate **thermal storage**. In these systems, the collector field is oversized to heat a storage system during the day so the additional steam it generates can be used to produce electricity in the evening or during cloudy weather. These plants can also be designed as hybrids, meaning that they use fossil fuel to supplement the solar output during periods of low solar radiation. In such a design, a natural gas-fired heater or gas-steam boiler/reheater is used. In the future, linear systems may be integrated with existing or new combined-cycle natural-gas- and coal-fired plants.

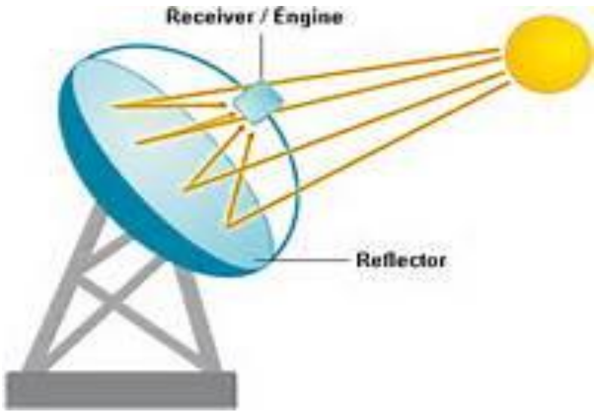
2.3 Solar tower technology

Power tower systems also called central receivers, use many large, flat heliostats (mirrors) to track the sun and focus its rays onto a receiver. As shown in Figure 3, the receiver sits on top of a tall tower in which concentrated sunlight heats a fluid, such as molten salt, as hot as 1,050°F. The hot fluid can be used immediately to make steam for electricity generation or stored for later use. Molten salt retains heat efficiently, so it can be stored for days before being converted into electricity. That means electricity can be produced during periods of peak need on cloudy days or even several hours after sunset.



[Fig.3 Solar tower technology]

2.4 Strilling dish technology



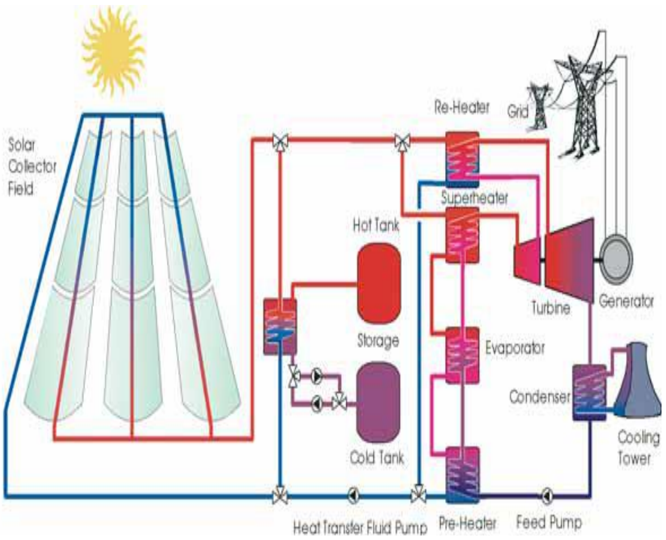
[Fig.4 Strilling dish technology]

Dish/engine systems use mirrored dishes (about 10 times larger than a backyard satellite dish) to focus and concentrate sunlight onto a receiver. As shown in Figure 5, the receiver is mounted at the focal point of the dish. To capture the maximum amount of solar energy, the dish assembly tracks the sun across the sky. The receiver is integrated into a high-efficiency "external" combustion engine. The engine has thin tubes containing hydrogen or helium gas that run along the outside of the engine's four piston cylinders and open into the cylinders. As concentrated sunlight falls on the receiver, it heats the gas in the tubes to very high temperatures, which causes hot gas to expand inside the cylinders. The expanding gas drives the pistons. The pistons turn a crankshaft, which drives an electric generator. The receiver, engine, and generator comprise a single, integrated assembly mounted at the focus of the mirrored dish.

3. Working

The system uses proprietary software to control thousands of tracking mirrors, known as heliostats, to directly concentrate sunlight onto a boiler filled with water that sits atop a tower. When the sunlight hits the boiler, the water inside is heated and creates high temperature steam. Once produced, the steam is used either in a conventional turbine to produce electricity or in industrial process applications, such as thermal enhanced oil recovery (EOR).

By integrating conventional power block components, such as turbines, with our proprietary technology and next-generation solar field design, projects using our systems are able to deliver cost-competitive, reliable and clean power when needed most. In addition, by integrating our technology with natural gas or other fossil fuels through a process referred to as hybridization, projects using our systems are able to further increase output and reliability.



[Fig.5 Schematic diagram of a steam cycle power plant with a parabolic trough collector and a thermal energy storage (Source: DLR)]

4. CSP

4.1 Absorber

Each type of CSP technology has its own absorber design. Parabolic troughs and Fresnel systems use linear receiver tubes composed of an external glass tube (coated to ensure high solar transmittance) and an internal metallic pipe (coated to ensure high solar absorption). Towers use central receivers. The towers currently in operation in Spain (PS10 and PS20) have a cavity receiver, formed of four vertical metallic panes in which saturated steam circulates. The panes are coated to increase solar absorption and arranged in a semi-cylindrical shape to minimize radiation and convection losses.

4.2 Heat transfer

All CSP technologies use heat transfer fluids (HTFs) to transfer the heat generated in the receivers to the power conversion unit(s). Parabolic troughs use synthetic oil with a maximum operating temperature of about 400°C. Future developments are around improved synthetic oil, molten salts or steam which allow higher temperatures.

Fresnel systems also use synthetic oils or water/steam. Tower systems use superheated steam or molten salt. Future developments are around gases (air, hydrogen, helium and carbon dioxide) and liquid metals. Dish systems can also reach high temperatures, and use Stirling engines with gas (hydrogen or helium) as the working fluid.

4.3 Thermal storage

An important attribute of CSP is the ability to integrate thermal storage. To date, this has mainly been for operational purposes, providing 3060 minutes of full-load storage. Plants are now being designed for 67.5 hours of full-load storage, which is enough to allow operation well into the evening. The solar field needs to be oversized so that heat supplied can operate the turbine during the day while charging the thermal storage.

4.4 Reflectors

All CSP technologies (dish, tower, trough and Fresnel systems) use reflectors. The most commonly used reflectors (thick glass mirrors) are made of silver-coated glass or tempered float glass with a glass thickness of 3-6 mm. Corrosion of the silver is prevented by use of copper and of special coatings (lacquers). Cerium is often used for polishing.

5. Why molten salt is used?

With photovoltaic energy prices dropping and concentrated solar power (CSP) towers operating at higher temperatures, the use of salts in CSP trough plants is being investigated to lower operating costs, improve plant efficiencies, and enable operation at higher temperatures. Most trough plants with synthetic or organic oil heat transfer fluids (HTFs) are limited to less than 400 °C.

Using salts can raise that temperature up to 550 °C, allowing steam turbines to operate at greater efficiency, among other advantages. Even though there are no commercial trough CSP plants using salt yet, new industrial-sized plants designed to incorporate their many advantages are currently entering the demonstration phase.

The molten salt mixture is both non-toxic and inert. Together with the Solar Reserve technology design, the use of molten salt represents the most flexible, efficient and cost-effective form of large scale energy storage system deployed today. This storage feature enables stable and dispatch able power delivery without the need for any backup fossil fuel such as the natural gas needed for many other CSP technologies. Solar Reserve's experience with molten salt includes salt specifications, equipment metallurgy, tank foundation design and engineering, as well as initial salt melting and commissioning processes.

5.1 FEATURES

Molten salt is circulated through highly specialized piping in the receiver (heat exchanger) during the day, and held in storage tanks at night – requiring no fossil fuels The tanks store the salt at atmospheric pressure Use of molten salt for both heat transfer and thermal energy storage minimizes number of storage tanks and salt volumes needed Molten salt is stored at 1050^0F (566^0C) until electricity is needed – day or night, whether or not the sun is shining As electricity is needed, molten salt is dispatched from the hot tank through a heat exchanger to create super-heated steam which then powers a conventional steam turbine The molten salt never needs replacing or topping up for the entire 30+ year life of the plant Heat loss is only 1^0F per day The salt, an environmentally friendly mixture of sodium nitrate and potassium nitrate, is able to be utilized as high grade fertilizer when the plant is eventually decommissioned. In addition to offering favorable storage conditions, as an HTF, molten salts also:

- Pollute less
- Nonflammable
- More abundant
- Lower vapor pressures
- Offer cost savings due to smaller thermal tanks and piping.

5.2 BENEFITS

Storage enables solar thermal power plants to operate just like a conventional fossil fuel or nuclear power plant, reliably generating electricity when it's needed most - but without the associated harmful emissions and without any fuel costs Solar thermal power plants with integrated molten salt energy storage can operate 24/7, proving baseload power for both on-grid and off-grid applications Integrated energy storage provides the ability to shift electricity generation to meet different profile needs and deliver firm, reliable power at high capacity value Molten salt thermal energy storage is the lowest capital cost energy storage system Solar thermal power plants with integrated energy storage are cost-competitive with any new build coal, natural gas, or nuclear technology Storage allows the facility to produce more than twice as much net annual output (megawatt hours) than any other solar technology Firm output ensures a more stable and secure transmission system.

6. Advantages of CSP

One major competitive advantage of concentrated solar power systems is that they closely resemble most of the current power plants. For example, much of the equipment now used for conventional, centralized power plants running on fossil fuels can also be used for concentrated solar power plants. CSP simply substitutes the use of concentrated solar power instead of combustible fossil fuels to produce electricity. This means that concentrated solar power can be integrated fairly easily into today's electric utility grid. This also makes concentrated solar power technology the most cost-effective solar option for large-scale electricity generation.

Environmental benefits of concentrated solar power

A huge environmental benefit that should not be overlooked is that simple and non-polluting concentrated solar power technology can be deployed relatively quickly and can contribute substantially to reducing carbon dioxide emissions. Each concentrated solar power plant provides emissions reductions compared to its natural gas counterpart; the 4,000 MW scenario in this study offsets at least 300 tons per year of NOx emissions, 180 tons of CO emissions per year, and 7,600,000 tons per year of CO2.

However, the cost of these technologies is still high to enter the global market on a larger scale, and needs to decrease before such an entry can be possible. Today, concentrated solar power technology has a cost somewhere between those of Photovoltaics and wind (1W=4EUR). Consequently, additional large-scale research efforts are necessary to further advance concentrated solar power technology to make it profitable and compatible as an alternative source of clean energy.

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