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Concentrated Solar Thermal Technology for Power Generation and its Case Studies

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ABSTRACT: The dependence on conventional energy sources since the Industrial revolution has increased extensively, affecting our environment. Over-exploitation of natural resources has led to the increased global average temperature rise of approximately 2°C per year and the emission of toxic gases and byproducts that can cause health complications. Further, it can cause acid deposition due to the reaction between Nitrogen oxides and Sulphur dioxide mixing with water, Oxygen, and other chemicals in the air which affects architecture, crops, marine, and wildlife. Hence, there is an urgent need to transition from conventional sources like fossil fuels to renewable energy. Solar energy is of two types: Solar Photovoltaic (PV) where Photovoltaic cells (panels of semiconductor cells) are used to collect both direct and scattered rays and convert them into electricity and Solar Thermal Energy where the sun's heat is captured. So our area of research involves CST technology and a detailed analysis and case study of India One Solar Thermal Power Plant located in Abu Road, Rajasthan, and PS10 located in Seville, Spain, and check its economic feasibility. There are benefits and drawbacks to CST technology. Even though India One and PS10 are noteworthy accomplishments in the field of renewable energy, there are still several issues with the technology that need to be resolved in order to make it a more viable and affordable choice.

KEYWORDS: CSP, CST, Concentrated Solar Thermal Technology For Power Generation, PS10 Spain, IndiaOne Abu

1. INTRODUCTION

This project discusses the harmful environmental implications of traditional energy sources, such as toxic emissions and global warming. It advises a switch to more environmentally friendly energy sources, such as solar energy, which has been used for many years but is currently undergoing large-scale development. Solar energy is split into two categories: solar photovoltaic and solar thermal. Low-temperature and concentrated solar thermal power technologies make up the latter category.

The latter uses collectors to concentrate the sun's rays in order to heat transfer fluid and produce electricity. This technique has the benefit of storing energy for up to 15 hours, making it practical for locations with strong sunlight. Case studies include the PS10 in Spain and the India One Solar Thermal Power Station.

1.1 World scenario

Several nations use different amounts of solar energy, with China having the most capacity with 208 GW and the United States coming in second with 1,740 MW. At least 37 nations will have a total solar power output capacity of over 1 GW by 2020. Since 2007, the usage of concentrated solar thermal (CST) has grown in popularity; in 2021, there will be 6,800 MW of installed capacity worldwide. Up until 2010, central power tower systems dominated the global market, but their capacity to operate at higher temperatures and promise greater efficiency has made them more popular since then. By the end of 2019, there will have been a total of 629 GW of solar PV installed in the world, demonstrating the dynamic growth of photovoltaics. The Ivanpah Solar Power Station (392 MW), the Ouarzazate Solar Power Project (in Morocco), and the Odeillo facility (in France), which serves as an industrial oven for testing new materials are examples of large CSP installations. While solar electricity has grown significantly in recent years, solar CSP has not kept pace due to technical difficulties and expensive costs; as of 2017, CSP made up less than 2% of the installed capacity of solar systems worldwide. There is still work to be done in this area, but CSPs can store energy at night, making them more competitive with dispatchable generators and baseload plants.

1.2 Domestic scenario

With a total collector area of 73,764 sq. metres, India has 318 concentrated solar thermal (CST) projects in various stages of implementation. The potential for energy output from completed installations is 39 Megawatts thermal. India's high irradiance and accessibility to inexpensive labour make it a promising market for CST expansion. In India, CSTs are used in a variety of industries including food, textile, automotive, and cookery. Almost 44949 sq. metres of the total land had, as of March 2017, been put into use thanks to UNDP-GEF funding, including 154 projects.

2. LITERATURE REVIEW

2.1 Research Gap

As a renewable energy source, concentrated solar power (CSP) or concentrated solar thermal (CST) technology provides a number of benefits, but it also has certain drawbacks. Its substantial footprint and poor efficiency are two such restrictions. Large acreage are needed for CSP facilities because of the high energy consumption, which might be an issue in densely inhabited areas. In any case, CSP plant efficiency ranges from 7% to 25%, indicating that there is space for improvement in CSP plant efficiency.

The greater investment and upkeep expenses of CSP in comparison to conventional power facilities are another disadvantage. Research reveals that solar thermal systems are more expensive than solar PV systems, with a levelized cost of electricity that ranges from $119 to $251 per MWh. Moreover, solar thermal power plants need a lot of water to run, which presents a challenge in dry regions. Aside from that, desert wildlife and endangered species may suffer as a result of solar thermal systems' utilisation of hundreds of enormous mirrors.

There are some restrictions with the most recent CSP/CST technologies as well. A significant restriction is the heat transfer fluid's maximum attainable temperature. The two materials that transfer heat most frequently today are molten salts and synthetic oils; however, salt cannot be employed because it decomposes too quickly at temperatures beyond 500°C. Research is therefore required to find salts that are stable over 800 °C as well as substitute substances such as solid particles and sCO2.The ability of the collector to concentrate Direct Normal Irradiance is directly impacted by filth, dust collection, and mirror deterioration, all of which have a negative impact on the collector's performance (DNI). While mirror erosion is a secondary phenomenon brought on by the impact of abrasive particles on the mirror surface, reducing mirror reflectance, soiling, and dust accumulation rates rely on the location and the frequency of high winds, sandstorms, etc., associated with any arid environment.

2.2 Objectives

Our focus will remain on the following areas throughout this project:

I. To study the components and working of the CST plant.
II. To examine the system models.
III. To do a case study on India's one CST plant and PS10, and check its economic feasibility.

3. CLASSIFICATIONS, COMPONENTS, METHODS & WORKING

3.1 Classification of CST technologies

Linear concentrating systems, solar power towers, and solar dish/engine systems are the three primary categories of concentrating solar thermal power systems. The energy from the sun is captured and focused onto receivers that run the length of long, rectangular, curved mirrors in linear concentrating systems. Through the tubes, fluid is heated by the concentrated sunlight, which is then transported to a heat exchanger to boil water and power a steam turbine generator. Parabolic troughs and linear Fresnel reflectors are the two main categories of linear concentrator systems. In order to work at temperatures exceeding 400°C with a concentration ratio of 30 to 100 times the average intensity, parabolic troughs have a long parabolic reflector that directs sunlight onto a receiver tube at the parabola's focal point.

Mirrors are used in Linear Fresnel Reflector (LFR) systems to direct sunlight onto a receiver. They focus the sun's energy to around 30 times its average intensity by using the Fresnel lens effect to generate a big diameter, short focal length collecting mirror. Several absorbers are located close to the mirror in the Compact Linear Fresnel Reflector (CLFR), a form of LFR technology, to reduce sunlight obstruction.

Heliostats, a vast array of sun-tracking mirrors, are used in solar power towers to reflect and concentrate sunlight onto a receiver at the top of the tower. Up to 1,500 times can be done to focus sunlight. A solar tower system having a total summer net producing capacity of 393 MW is the Ivanpah Solar Power Plant in California.

A mirror dish is used in a solar dish/motor system to direct sunlight toward a heat receiver, which then gathers and distributes the heat to the motor generator. It moves a piston with the aid of a Stirling engine, creating a mechanical force that powers an alternator or generator to create electricity. This system has a high concentration rate, a working fluid temperature above 750°C, and it is always pointed straight at the sun. The utilised generator can collect energy from numerous installations and convert it to electricity at a central location, making it useful for remote locations.

3.2 Components of a solar dish type CST Plant

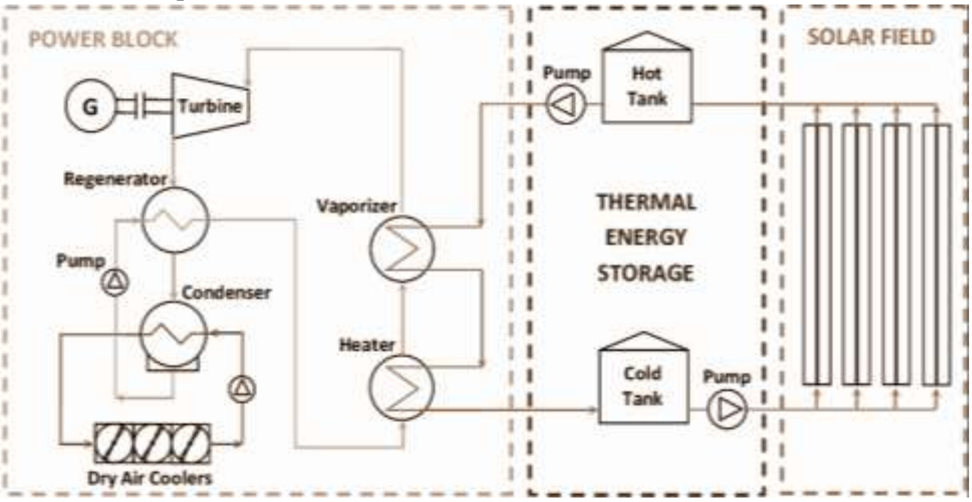
The solar dish/motor system, which consists of a mirror dish that directs the sun's light towards a central cavity receiver and employs a Stirling engine to generate mechanical force that powers a generator or alternator to produce electricity, can be used in a solar power plant. The solar dish is ideal for isolated places since it is always pointed directly at the sun, has a high concentration rate, and has a working fluid temperature above 750°C. Another tool used in solar power plants is a heliostat, which has a mirror that rotates to continue reflecting sunlight at a predefined target, offsetting the apparent motions of the sun in the sky. The receiver unit also functions as a heat storage device, and it can be made more efficient by sandwiching a double-coil heat exchanger between an inner and outer shell made of cast iron grit. The completely automated tracking system has actuators and gears that allow for the controlled rotation of solar panels around single or two axes. A solar turbine that produces steam by heating a transmission fluid with parabolic mirrors is also available. Finally, a storage unit can be used in conjunction with solar energy technology to help the grid cope with fluctuations in solar energy flow even when the sun isn't shining.

3.3 Methods and working of solar dish type CST plant

The sun is focused by the dish/engine combination onto a receiver, which produces steam that drives a turbine, which in turn powers a generator to provide electricity. CSP produces steam using sunlight rather than fossil fuels. A tube containing hydrogen or helium gas and an external internal combustion engine can also be integrated with the receiver. The gas inside the tube heats up as sunlight strikes the receiver, expands, pushes a piston, and rotates a crankshaft that powers the generator. The focal point of the dish is mounted using a single assembly that includes the receiver, motor, and generator.

4. FLOWCHARTS, MODELLING AND CASE STUDY

4.1 Process flow chart of CST plant



4.2 Case study-1

The Brahma Kumaris headquarters, with a capacity of 25,000 people, is powered by "India One," a 1 MW electrical Sun Thermal Power Plant with 16 hours of thermal energy storage. The Shantiban complex on Abu Road will be powered by this off-grid power station.

The facility includes 770 parabolic reflectors, each measuring 60 square metres, and each one is outfitted with a fully automatic dual-axis monitoring mechanism that allows it to detect the Sun's position both daily and seasonally. The extraordinary solar-grade mirrors with a 93% reflectivity are used in the reflectors' innovative static focus design.

770 specifically created cast iron cavity receivers immediately produce superheated steam at pressures of 42 bar and temperatures up to 450 °C. The receivers are distinguished by their static design, which is low maintenance, affordable, and long-lasting.

Each receiver weighs three tonnes of cast iron and serves as a heat reservoir when it's dark and partly overcast outside. A steam coil encircling the cast iron core serves as a steam generator by exchanging heat from the iron core with water. The hot steam travels through a turbine attached to an electricity-generating generator.

Because the technology was created internally as part of the Made in India effort, it serves as a wonderful example of thermal storage solar power plants around the globe. Early in 2017, India One was successfully put into service. It's network-enabled 2-axis tracking with remote access and monitoring allows for efficient and simple maintenance.

The plant has equipment for real-time, web-enabled performance evaluation and remote monitoring for simple maintenance. It has many distinctive characteristics, such as a 60 m2 parabolic reflector built with space frame structural engineering that provides a static focus of high temperature, a static cast iron receiver that can be mounted on the ground at a fixed location, and complete automation of the reflector for daily tracking of the sun as well as for seasonal tracking and seasonal change adjustments using an optical camera-based tracking mechanism.

The solar reflector produces superheated steam directly from 300–400 °C without the use of any heat exchangers or heat transfer fluids, increasing turbine efficiency. For the past four years, the plant has produced an average of 3 million electrical units annually (including solar thermal and solar power for the India One campus).

India One has produced an average of 12 million electrical units every year since it began. The average savings over the last four years have been over $600,000 to date, and the net savings from electricity generation are roughly $150,000 per year. With an average CO_2 emission reduction of around 10,200 tonnes of carbon over the previous four years, the plant's power generation will reduce CO_2 emissions by about 2,550 tonnes annually.

4.2.1 System model

The modeling of a system that transfers heat using a helical coil is shown in the article. A receiver/storage model is used to implement the simulation, and it takes into consideration both the temperature of the cast iron storage material and the fluid characteristics inside the tube. Pressure drop inside the tube can also be accounted for by the model, albeit this feature has not yet been put to the test.

Despite the fact that a double coil receiver model has been created, the simulation uses a single coil receiver model due to time constraints. When comparing the average storage temperature, the models produce excellent results.

The article displays the modeling of a system that transfers heat using a helical coil. The simulation is implemented using a receiver/storage model that accounts for both the fluid properties inside the tube and the temperature of the cast iron storage material. Although this functionality has not yet been tested, the model can also account for pressure drop inside the tube.

Although a double coil receiver model has been developed, due to time restrictions the simulation uses a single coil receiver model. The models deliver superior results when comparing the typical storage temperature.

The process's exact technological implementation at the conclusion of discharge is still up in the air. Meteonorm, a program for gathering data on the world's climate, is used in the simulations' weather data.

Controller settings

In the simulation, a set of controller settings govern the hydraulic cycle. The cavity entrance closes to stop more radiation from entering until the temperature drops below the safety threshold if the storage temperature reaches the maximum of 500°C. In the event that steam is generated during discharge, discharge is halted if the steam temperature at the module's exit exceeds 450°C. A figure provides a summary of these control variables.

When the steam temperature at the module's exit exceeds 280°C, the discharging operation is terminated for the day and a minimum steam quality is established. More receivers may serve as evaporators near the discharge's conclusion. The stipulated mass flow of 8000 kg/h at the turbine is maintained, and the mass flow rate via the module is computed assuming that all of the system's modules are discharged simultaneously.

The feed water temperature is fixed at 80°C, and the system pressure is set at 42 bar. The receiver store is only opened when the solar hour angle hits -80° and the cavity is only opened if a minimum DNI of 100 W/m2 is registered. This takes into account the Scheffler-daily Reflector's rotation span.

Simulation results

A full year's worth of Meteonorm weather data (01.01–31.12.) has been simulated for the system, which consists of a module of 15 receiver/storage units connected in series.

Discussion of model limitations

The simulation did not take pumping power or pressure decrease into account. To incorporate the feed water evaporation process in the module into the simulation, more discussion is required. To include the operation of the receiver shutter in the simulation, a thorough explanation of the opening and closing of the receivers based on storage temperature and DNI availability is also necessary. During the visit to the IndiaOne site, the discharging method should be thoroughly addressed together with other controller settings and simulation parameters. The simulations shown solely account for the WRST site's high DNI period; during intermittent DNI periods, alternative needs might apply. Although a single-coil receiver model was used for the simulations, it is anticipated that a double-coil receiver will exhibit comparable qualitative behavior. The absolute numbers, however, will be different. As a result, the simulations' resulting relative changes can be qualitatively applied to various setups. The assumption will be tested for at least one case comparison by utilising the new receiver model with the same configuration and settings after modifying its parameters based on measurement findings.

4.2.2 Economic feasibility

The total cost of construction of India One concentrated solar thermal power plant in Abu Road, Rajasthan, India was approximately INR 1,475 crore (equivalent to around USD 223 million) at the time of its completion in 2014. It is worth noting that this is an approximate figure, and the actual cost may have varied due to various factors such as currency fluctuations and other project-specific factors.

4.3 Case study II

The PS10 solar thermal tower plant generates direct saturated steam at low pressure and temperature. It has a receiver mounted on a 100-meter tower and 624 heliostats placed in circular rows to reflect solar light. The heliostats are spherically curved and equipped with high-reflectivity mirrors to reduce losses caused by spillage, shadowing, blocking, and cosine effects. A mechanical drive controlled by a local control system provides the 2-axis sun tracking necessary for projecting the sun's picture onto the receiver. This system is in charge of determining the current position of the heliostat and comparing it to the required position to assault the receiver at a predetermined targeting point. It receives sun position information from a higher control level.

4.3.1 System model

Using saturated steam and a cavity receiver used in the PS-10 facility in Seville, improved optical performances and a 16.4% solar to electricity efficiency are achieved. It has a solar field with 624 heliostats arranged in a north arrangement, a small direct steam storage of around 25 minutes, and a net power production of 11 MWel. The on-design and annual performances of the solar plant were modelled using the modelling tools DELSOL3 and Thermoflex 23®, with DELSOL3 being utilised to evaluate optical efficiency and IAM (Incidence Angle Modifier) maps.

$$\eta_{overall} = \eta_{optical} \cdot \eta_{thermal} \cdot \eta_{piping} \cdot \eta_{net\_PB} \cdot \eta_{aux\_SF} = \frac{E_{el,annual}}{E_{SUN}} \quad (1)$$

where:

- $\eta_{optical}$ is the optical efficiency that compares the radiation absorbed by the receiver to the direct normal solar irradiation;
- $\eta_{thermal}$ is the thermal efficiency that takes into account the receiver thermal losses;
- η_{piping} evaluates the impact of piping thermal losses (also nighttime losses) on the HTF transferred thermal power
- η_{net_PB} expresses the efficiency conversion of the thermal input into electricity;

Sandia National Laboratories' DELSOL3 performance and design software was used to assess the optical performance of two solar tower installations. The software needs details like the solar plant's geographic coordinates, the state of the atmosphere, the heliostats' geometrical specifications, and the receiver type. The programme determines the optical effects of the heliostat field, which is broken down into six factors: attenuation due to the atmosphere, average mirror reflectivity, shading and blocking losses, and the percentage of reflected energy that reaches the receiver surface. The optical efficiency is calculated as the sum of these six efficiencies. All terms are evaluated in terms of power using equation (1), while in the annual assessment, energy is used throughout an hourly time period of more than 8,760 hours.

$$\eta_{optical-DELSOL3} = \eta_{cos} \cdot \eta_{reflect} \cdot \eta_{shadow} \cdot \eta_{block} \cdot \eta_{attenuation} \cdot \eta_{spillage} \quad (2)$$

where,

η_{cos} is the solar radiation reduction, proportional to the cosine of the angle between the sun rays and the heliostat surface normal;

$\eta_{reflect}$ is the average mirror reflectivity;

η_{shadow} is related to the shading losses, due to the shadow cast by a mirror onto the mirrors behind it and takes into account the receiver tower shadow on the whole solar field

η_{block} is related to the blocking losses, due to the radiation reflected by a heliostat on the back of another heliostat;

$\eta_{attenuation}$ takes into account the atmospheric attenuation of the radiation between the heliostat and the receiver;

$\eta_{spillage}$ represents the fraction of the energy spot reflected that hits onto the receiver surface.

The optical efficiency can thus be obtained as the product of the six above mentioned efficiencies:

Excel was used to generate the solar field optical models for the PS10 plant in DELSOL3, and aerial photographs of the facilities were used to estimate the locations of each heliostat for the two fields. With a focus point equal to the slant range to the receiver, it was believed that each heliostat was spherically curved. The PS10 heliostats' mirror reflectivity was estimated to be 88%. The management of input and output as well as the post-processing of the outcomes were done using an Excel spreadsheet. The receiver absorbance was not taken into account when calculating efficiency.

	PS10
Number of heliostats in the field	624
Field shape	North
Heliostat width (m)	12.84
Heliostat height (m)	9.45
Curvature	Spherical
Reflectivity	0.88
Reflective/Total area ratio	1
Total Error on Reflected ray (mrad)	2.9
Focus	Slant Range

PS10 heliostat field main geometrical and optical assumptions

	PS10
Receiver elevation (m)	93.2
Tower height (m)	107.7
Tower diameter (m)	18
R (m)	7
W (m)	4
Aperture height (m)	16
Aperture width (m)	14.83
Panel height (m)	12
Single panel width (m)	5.36
Receiver height (m)	-
Receiver diameter (m)	-

PS10 receiver geometrical assumptions used as input in DELSOL3.

Using the DELSOL3 optical simulation software, the study examined PS10, the solar thermal power plants, for their performance. Using Excel and aerial photographs of the plants, the PS10 solar field models were built utilising the data that was accessible in the literature. The optical errors were taken to be identical in the two configurations, and the heliostats were assumed to be spherically curved with an 88% mirror reflectivity. The towering shadow was explained by supposing that it was a cylinder with height and diameter determined by the tower.

The study contrasted the PS10 plant's DELSOL3 results with information from the literature. Using the Excel interface and four different DELSOL3 runs, the energy flux on the four panels of the PS10 cavity receiver was generated. The peak flux was roughly 10% greater than experimental data on both days, according to a comparison between the observed solar flux on the panels and the DELSOL3 software's output, although there was good agreement in terms of total concentrated solar radiation.

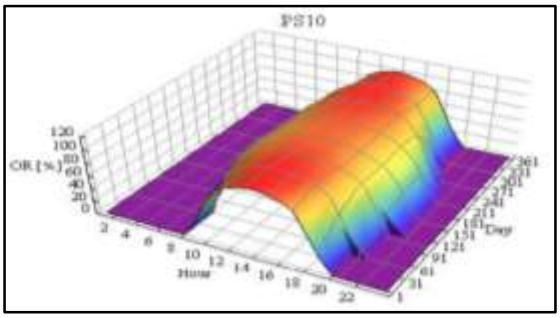
The optical performance of the heliostats in the simulated field for a chosen location of the sun in the sky might also be obtained using the DELSOL3 software. Due to the PS10's north-facing solar field configuration, the heliostats' efficiency increased over the winter. The optical efficiency matrixes function of azimuth and zenith angle were then created using the software and used as inputs for the Thermoflex 23® Solar Tower component. On the spring equinox at solar noon, the sizes of the Thermoflex solar fields were adjusted to match the sizes of the solar fields in real plants as well as the solar radiation reaching the receivers. The results section lists the annual optical efficiency figures for the two plants.

Solar plant simulation

To examine the PS10 receiver's performance, the Thermoflex model is used. It takes into account the thermal losses brought on by convection and radiation, as well as the losses that happen when solar radiation is reflected by the receiver. Thermoflex calculates these losses as a portion of the solar radiation that the receiver absorbs in order to streamline the modeling process. The model is calibrated to function under nominal settings, but it also considers the performance changes that take place when the system works in conditions that are not intended for it. Variations in steam turbine pressure and efficiency are among these changes. Thermoflex 23 consolidates the many components of the steam turbine to increase the precision of off-design performance forecasts. When operating at partial load, users have the option to pick the steam-turbine control modality.

Results

The figure below shows the optical ratios (OR) of the PS10 solar power tower, representing the ratio between off-design optical efficiency and the optical efficiency at reference conditions. The reference condition was selected as the 21st of March at solar noon, as the incidence angle is not useful for identifying a reference condition in solar tower systems.



Optical Ratios (OR) for PS10 as a function of the hour of the day and of the day of the year

The table summarizes the terms in which the optical efficiency of the solar tower is split, including absorbance contribution not considered in DELSOL3.

	PS10	
	Nominal	Annual
η_{cos} (%)	92.34	84.40
$\eta_{reflect}$ (%)	88.00	88.00
η_{shadow} (%)	99.93	96.56
η_{block} (%)	99.24	99.09
$\eta_{attenuation}$ (%)	95.44	95.50
$\eta_{spillage}$ (%)	99.34	99.39
$\eta_{absorbance}$ (%)	98.00	98.00
$\eta_{optical}$ (%)	74.87	66.10
$\eta_{defocus}$ (%)		97.90

PS10 nominal and annual optical efficiency, split into different contributions

	PS10
$\eta_{optical\ nominal}$ (%)	74.87
$\eta_{overall\ nominal}$ (%)	19.55
$\eta_{optical\ yearly}$ (%)	64.72
$\eta_{thermal\ yearly}$ (%)	92.83
$\eta_{piping\ yearly}$ (%)	98.85
$\eta_{net\ PB\ yearly}$ (%)	27.33
$\eta_{aux\ SF\ yearly}$ (%)	98.85
$\eta_{overall\ yearly}$ (%)	16.05

The "chain of five efficiencies" for PS10 plant and the resulting overall efficiency

4.3.2 Economic feasibility

Owned by Abengoa Company, PS10 was constructed in Spain with a 25-year lifespan. It was built in 2007 for a cost of €35 million (US $ 46 million), jointly sponsored by the Andalusia Regional Government ($2.2M) and the European Commission ($6.6M) under the 5th Framework Programme. A Spanish law that offers a solar tariff of roughly $0.24 per kWh over the price of pool market power supports the tower's specific cost of about $4200/kW gross and helps it produce about 24 GWh of electricity yearly. The overall lifecycle cost of PS10 is approximately $138 million, of which 4.5% goes to operating and labour costs and 3% to the repair of worn-out components in the solar power tower system. Costs associated with running and maintaining PS10 are $82.3M, while the electricity generation cost is equal to 0.23 $/kWh.

Life-cycle cost of PS10 in Spain

5. CONCLUSION

In terms of annual performance, the article contrasts two commercial concentrating solar power facilities, India One and PS10. Several simulation programmes were utilised, each of which was adjusted for the facts at hand. India One is a best-practice initiative for CSP projects in India that keeps costs down and also focuses on social good. Via a teaching facility in Rajasthan, WRST might disseminate the knowledge it has learned about solar steam and photovoltaic power. The world's first commercial solar power tower, known as PS10, was a ground-breaking initiative that opened the door for other solar power plants in Spain and other nations. It benefited local economies, the environment, and Spain's effort to diversify its energy sources. The PS10 plant is a crucial illustration of how solar energy can generate safe, dependable, and environmentally friendly electricity.

➔ Cost Comparison

Solar thermal power plant construction prices vary depending on a number of variables, including location, size, technology, labour costs, and the regulatory environment. For instance, in 2014, it cost INR 1,475 crore (USD 223 million) to build the India One concentrated solar thermal power plant in Rajasthan. PS10 in Spain, on the other hand, costs €35M (USD 46M) to build in total. Comparing the entire cost of building is not a good idea, though, as it may vary greatly depending on the location and other factors. Long-term costs of running and maintaining solar thermal power facilities should also be considered, as they may differ depending on things like the quality of the equipment and availability of competent labor.

According to the International Renewable Energy Agency (IRENA), the average cost of building a solar thermal power plant in India is about $3,500 per installed kilowatt (kW), compared to about $4,500 per kW in Spain because India has lower labour costs and a legislative environment that is supportive of renewable energy projects.

Thus, the economic feasibility and cost-benefit analysis of solar thermal power plants in India and Spain should be considered before making any decision.

In conclusion, building a solar thermal power plant in India is frequently less expensive than doing so in Spain. Before making a choice, it is crucial to weigh all the relevant aspects, including location, technology, the regulatory environment, labor costs, and long-term operational and maintenance expenses.

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