CONCENTRATED SOLAR THERMAL POWER SYSTEM

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ABSTRACT:

This paper scrutinizes about Solar energy which is a virtually inexhaustible energy resource, and thus, has great potential in helping meet many of our future energy requirements. Current technology used for solar energy conversion, however, is not cost effective. In addition, solar thermal power systems are also generally more efficient as compared to fossil fuel based thermal power plants. There is a large variety of systems for solar thermal power generation, each with certain advantages and disadvantages. A distinct advantage of solar thermal power generation systems is that they can be easily integrated with a storage system and/or with an auxiliary heating system (as in hybrid power systems) to provide stable and reliable power. Also, as the power block of a solar thermal plant resembles that of a conventional thermal power plant, most of the equipment and technology used is already well defined, and hence does not require major breakthrough research for effective utilisation. Manufacturing of components, too, can be easily indigenized. Concentrating solar power is relatively low cost and have the ability to deliver power during periods of peak demand-when and where it is needed-means that it can be a major contributor to the world's future needs of energy. Concentrating solar plats differ from traditional photovoltaic technologies.

KEYWORDS: **Heliostats, Mirrors, Solar Tower, Convex lens, Temperature detector, Boiler**

1. INTRODUCTION:

Concentrating solar thermal (CST) technologies can produce electricity on demand when deployed with thermal energy storage, providing a dispatchable source of renewable energy. Therefore, solar thermal electricity (STE) can be provided by smoothing the variability of the energy resource and taking advantage of peakpower prices.

Furthermore, CST technologies can be applied in industrial processes to desalinise water, improve water electrolysis for hydrogen production, generate heat for combined heat and power applications, and support enhanced oil recovery operations. The use of these technologies in a wide range of applications encourages the improvement of their efficiency, which depends on the direct-beam irradiation.

Consequently, arid and semi-arid areas with clear skies are desirable locations where STE plants are installed. In these facilities, curved mirrors are used to concentrate solar radiation onto a receiver which is heated by the radiation. The heat absorbed is transferred to a fluid that passes through the receiver. In order to obtain concentrating solar thermal power, the heated fluid drives a turbine that converts solar heat into electricity.

The STE industry has experienced robust growth since 2009 which has been most notable in Spain and the United States, and initiated in many other countries with an increasing energy demand. The largest plants considering the countries with initial STE development are located in United Arab Emirates and India, but others are under construction in Morocco and South Africa. Smaller solar fields, often integrated in larger fossil fuel plants, also can be found in Algeria, Australia, Egypt, Italy and Iran. Furthermore, market prices seem to befalling because new technologies have reached commercial maturity and new concepts have emerged.

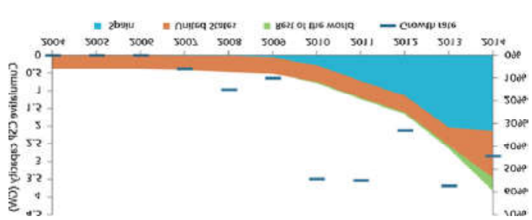

Fig.1.1 Global cumulative growth of STE capacity

2) CONCENTRATION OF SOLAR RADIATION:

Solar energy is the most abundant energy resource on earth and the solar radiationreaching the earth's surface equals about 1 kilowatt per square metre (kW/m2) under clear conditions when the sun is near the zenith. It is comprised of two components: direct or beam radiation, which comes directly from the sun's disk; and diffuse radiation, which reaches the earth after being scattered in all directions by the atmosphere. Hence, global solar radiation is the sum of both components (direct and diffuse radiation).

3) CONCENTRATING SOLAR THERMAL (CST) TECHNOLOGIES:

STE plants are gaining in popularity with advances in technology. There is a variety of concentrating solar thermal technologies available nowadays, being solar thermal collectors the major component of solar power systems. As previously stated, these collectors receive the incoming radiation and concentrate solar rays to heat a fluid, which then directly or indirectly drives a turbine and an electricity generator. Theconcentration of sunlight allows the fluid to reach working temperatures high enough to ensure affordable efficiency in turning the heat into electricity, whilelimiting heat losses in the receiver.

The four main commercial CST technologies are distinguished by the way they focus the sun's rays and the technology used to receive the solar energy (Fig. 3.1) parabolic-trough collector (PT), solar tower (ST), linear Fresnel (LF) and parabolic dish (PD). They can be classified according to the focus type (line focus or point one), depending on the receiver type (fixed or mobile) or considering the concentration level (medium or high concentration). In solar tower and linear Fresnel, the receiver remains stationary and mechanically independent from the concentration system, which is common for all the mirrors. However, the receiver and concentration system move together in PT and PD technologies, enabling an optimal arrangement between concentrator and receiver.

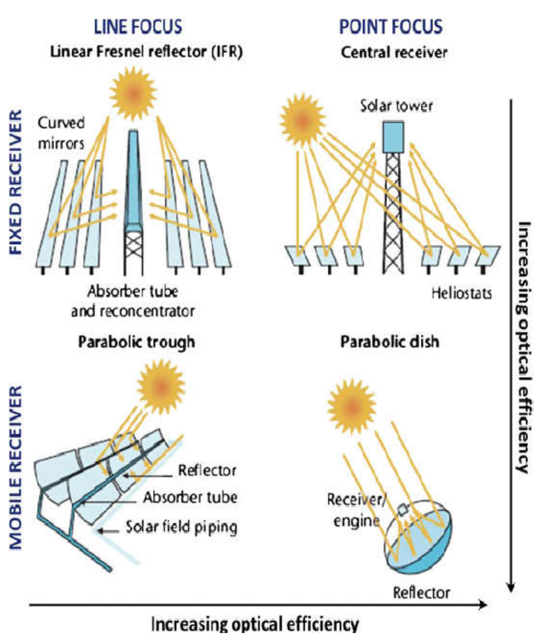

Fig.3.1 STE technologies

The temperature reached on the receiver is related to the concentration ratio of the collector (Fig. 3.2). Thus, PT and LF reflect the solar rays on a focal line with concentration factors on the order of 60–80 (medium-concentration technologies) and maximum achievable temperatures of about 550 °C. In PD and ST plants, mirrors concentrate the sunlight on a single focal point with higher concentration factors and operating temperatures (high-concentration technologies). On one hand, central receivers achieve a concentration ratio of around 600 and temperatures of 800 °C, and, on the other hand, parabolic dishes reach concentration ratios greater than 1000 that lead to temperatures of 1600 °C. Furthermore, solar furnace is used as test facility able to concentrate around 10,000 times the sunlight reaching temperatures above 2000 °C.

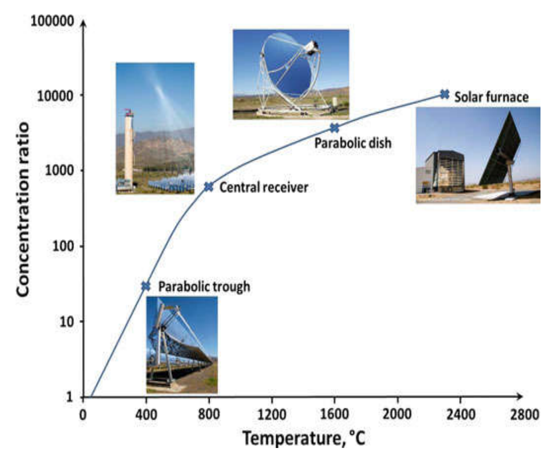

Fig. 3.2 Concentration ratio of the STE technologies

3.1 Parabolic Trough Collectors:

This is the most mature CST technology, accounting for more than 90 % of the currently installed STE capacity. As illustrated in Fig. 3.3, solar fields using trough systems utilise curved highly-reflective mirrors which focus sunlight onto a linear receiver attached to the focal axis of its parabola. The collectors are connected together in long lines of up to 100 m and track the sun's path throughout the day along a single axis (usually East to West).

The parabolic mirrors are made by bending a sheet of reflective material (silvered low-iron float glass) into a parabolic shape and send the solar beam onto the receiver or absorber tube filled with a specific heat transfer fluid. These metal tubes or pipes have a special coating to maximise energy absorption and minimise evacuated glass envelope.

The thermal energy is removed by the heat transfer fluid (e.g. synthetic oil, molten salt) flowing in the heat-absorbing pipe and transferred to a steam generator to produce the super-heated steam that drives the turbine. Once the fluid transfers its heat (temperatures of up to 400 °C), it is recirculated into the system for reuse. The steam is also cooled, condensed and reused. Furthermore, the heated fluid in PT technology can also provide heat to thermal storage systems, which can be used to generate electricity at times when the sun is not shining.

Most PT plants currently in operation have capacities between 14 and 80 MWe, efficiencies of around 14–16 % (i.e. the ratio of solar irradiance power to net electric output) and maximum operating temperatures of 390 °C, which is limited by the degradation of synthetic oil used for heat transfer. The use of molten salt at 550 °C for heat transfer purposes in PT plants is under investigation. High temperature molten salt may increase both plant efficiency (e.g. 15–17 %) and thermal storage capacity.

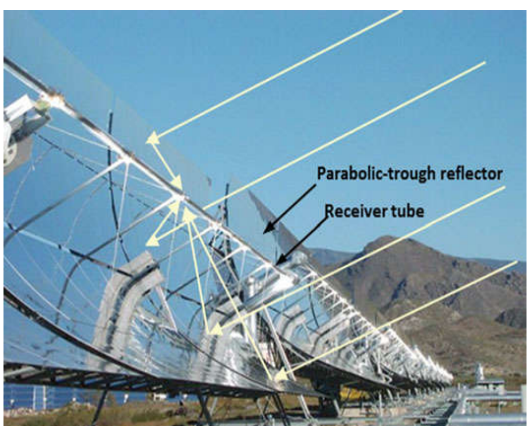

Fig. 3.3 Parabolic trough collector

3.2 Linear Fresnel detector: Linear Fresnel (LF) is similar to PT collector, with slight differences (Fig. 3.4). It uses a series of ground-based, flat or slightly curved mirrors placed at different. Linear Fresnel angles to concentrate the sunlight onto a fixed receiver located several meters above the mirror field. Each line of mirrors is equipped with a single axis tracking system to concentrate the sunlight onto the receiver which consists of a long, selectively-coated tube. The facility usually uses water as heat transfer fluid, which passes through the receiver and it is converted into steam (DSG or Direct Steam Generation). Since the focal line in the LF plant can be distorted by astigmatism, a secondary mirror is placed above the receiver to refocus the sun's rays. Alternatively, multi-tube receivers can be used to capture sunlight with no secondary mirror.

Flat mirrors and shared receivers result in lower expenses, while at the same time, this technology benefits from the long-term success. Furthermore, similar to the PT system, linear Fresnel does not need two-axis tracking since the sun will be focused on a part of the system throughout the year.

The main advantages of LF compared to PT systems are the lower cost of ground-based mirrors and solar collectors (including structural supports and assembly). While the optical efficiency of the LF system is lower than that of the PT systems (i.e. higher optical losses), the relative simplicity of the plant translates into lower manufacturing and installation costs compared to PT plants.

Thus, the mirror aperture can be augmented more easily than with troughs, and secondary reflection makes possible higher concentration factors, decreasing thermal losses. However, LF has greater optical losses than troughs when the sun is low in the sky. This reduces power generation in early morning and late afternoons, and also in winter, but can be overcome in part by the use of higher operating temperatures than PT plants.

Therefore, it is not clear whether LF electricity is cheaper than the one from PT plants. Furthermore, as LF systems use direct steam generation, thermal energy storage is likely to be more challenging and expensive. Thus, LF is the most recent CST technology with only a few plants in operation. The largest solar thermal plant using LF technology is Puerto Errado in Spain with a capacity of 30 Mwe.

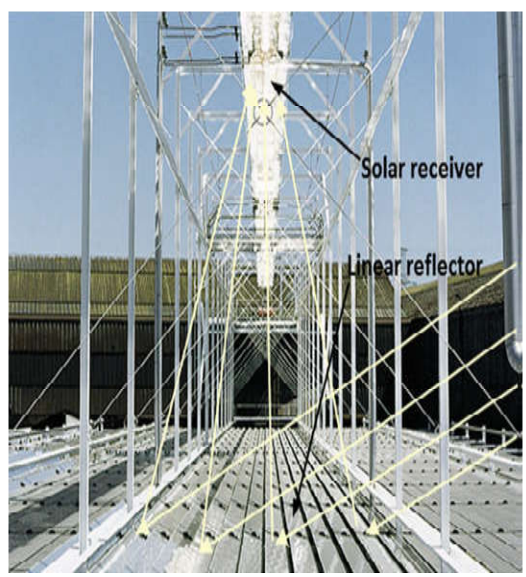

Fig. 3.4 Linear Fresnel detector

3.3 Solar Tower: In the ST plant (salso called central receiver systems (CRS) or power tower, a large number of computer-assisted mirrors (heliostats) track the sun individually over two axes. Heliostats are less expensive than trough mirrors because they utilise standard flare glass, instead of glass that is manufactured at specific curves. They concentrate the solar radiation onto a single receiver at the top of a central tower where the solar heat drives a thermodynamic cycle and generates electricity. ST plants can achieve higher temperatures than PT and LF systems because they have higher concentration factors (Fig. 3.5). The CRS can use water-steam (DSG), synthetic oil or molten salt as the primary heat transfer fluid.

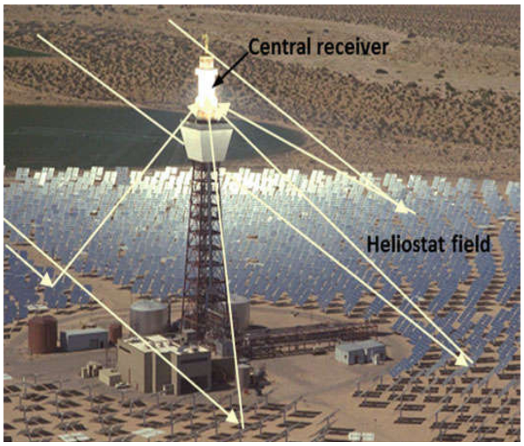

Fig. 3.5 Solar tower

The use of high-temperature gas is also being considered (e.g. atmospheric air in volumetric receivers).

In a direct steam ST, water is pumped up the tower to the receiver, where concentrated thermal energy heats it to around 550 °C. The hot steam then powers a conventional steam turbine. When DSG is used as heat transfer fluid, it is not required a heat exchanger between the primary transfer fluid and the steam cycle, but the thermal storage is more difficult.

Depending on the primary heat transfer fluid and the receiver design, maximum operating temperatures may range from 250 to 300 °C (using water-saturated steam) to 390 °C (using synthetic oil) and up to 565 °C (using molten salt and water-superheated steam). Temperatures above 800 °C can be obtained using gases (e.g. atmospheric air). Thus, the temperature level of the primary heat transfer fluid determines the operating conditions (i.e. subcritical, supercritical or ultrasupercritical) of the steam cycle in the conventional part of the power plant.

ST plants can be equipped with thermal storage systems whose operating temperatures also depend on the primary heat transfer fluid. Today's best performance is obtained using molten salt at 565 °C for both heat transfer and storage purposes. This enables efficient and cheap heat storage and the use of efficient supercritical steam cycles.

High-temperature ST plants offer potential advantages over other CST technologies in terms of efficiency, heat storage, performance, capacity factors and costs. In the long run, they could provide the cheapest STE, but more commercial experience is needed to confirm these expectations. However, a large ST plant can require thousands of computer-controlled heliostats, that move to maintain point focus with the central tower from dawn to dusk, and they typically constitute about 50 % of the plant's cost. The largest solar thermal plant operating through power towers is the Ivanpah Solar Power Facility in the USA, with a capacity of 392 MWe. The plant gathers three distinct towers, each with its own turbine, based on DSG technology and no storage. There are two more facilities in Spain, each with approximately 20 MWe of capacity, and several other facilities with lower capacities in Turkey, India, and other countries.

Larger ST plants have expansive solar fields with a high number of heliostats and a greater distance between them and the central receiver. This results in more optical losses, atmospheric absorption and angular deviation due to mirror and sun-tracking imperfections. Therefore, ST still has room for improvement of its technology.

3.4 Parabolic Dish:

Parabolic dish (PD) systems (Fig. 3.6) consist of a concave dish shaped concentrator that reflects sunlight into a receiver placed at the focal point of the dish. The receiver may be a Stirling engine or a micro-turbine. PD requires two-axis sun tracking system to follow the sun from east to west during the day, and from north to south throughout the year. This technology offers very high concentration factors and operating temperatures.

To date, there are no large utilities using PD technology, due to several difficulties.

The design of reliable engines for large plants is still under development. In addition, the initial cost of such systems is high in comparison with the CST

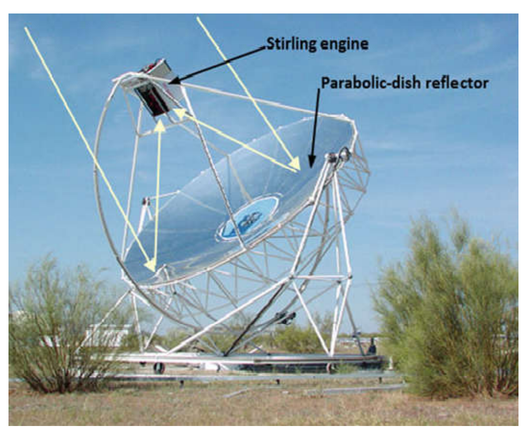

Fig. 3.6 Parabolic dish

technologies previously described, and there are also challenges related to the storage capability. Nevertheless, the Stirling dish system has the highest efficiency in the conversion from heat to electricity, with a net average annual yield rate that is 18–23 % higher than any other solar energy system.
Therefore, the main advantages of PD systems include high efficiency (i.e. up to 30 %) and modularity (i.e. 3–50 kW), which is suitable for distributed generation. Unlike other STE options, PD systems do not need cooling systems for the exhaust heat. This makes PD suitable for use in water-constrained regions, though at relatively high electricity generation costs compared to other CST technologies.
PD technology is currently considered a potential technology for STE generation and many pilot projects have been launched in the USA and Spain. However, the PD system is still under demonstration and investment costs are still high. Thus, with more research and development, it could be a potential alternative candidate technology for STE plants.

3.5 Solar Furnace: Solar furnaces reach the highest energy levels in concentrating solar systems. Therefore, they are used as a test setup for high-temperature processes and other applications, such as material treatment, development and investigation of new solar receivers, and simulation of thermal effects from highly concentrated heat flux, among others. The facility (Fig. 3.7) consists of an optical system with one or more heliostats, which reflect the solar radiation onto a concentrator. This reflector can be composed by a parabolic mirror or a group of spherical mirrors. The furnace power can be

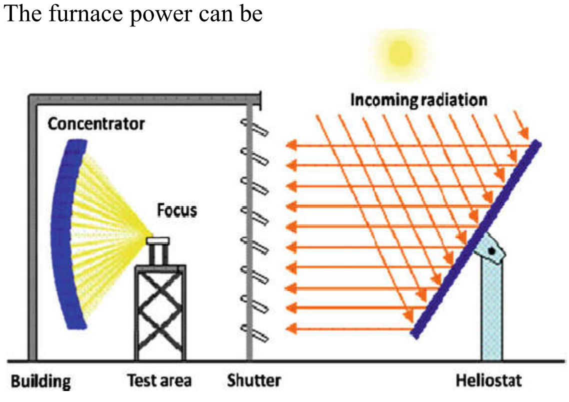

Fig. 3.7 Solar furnace

attenuated by a shutter, which control the amount of solar radiation received onto the concentrator. The concentrated radiation reaches the test area, which is located at the concentrator focus.

4) STATUS OF CST TECHNOLOGIES

4.1 Medium-Concentration Solar Technology: Medium-concentration solar power plants use the line focusing parabolic solar collector at a temperature of about 400 °C. Significant advances have been made in parabolic collector technology together with organic Rankine cycle technology to improve the performance of parabolic trough STE plant. Furthermore, the traditional sun-tracking unit with sensors that detect the position of the sun has been replaced by a system based on the calculation of the sun position using a mathematical algorithm.
The Solar Energy Generating System in the USA is the largest parabolic trough power plant complex in the world, with a capacity of 354 MWe. A recent development in cost effective concentrators is the design of Euro Trough, a new parabolic trough concentrator, in which an advanced lightweight structure is used to achieve cost efficient solar power generation. Parabolic trough STE plants can collect up to 70 % of the incident solar radiation and achieve a peak electrical conversion efficiency of 20–25 % whose improvement is the main challenge for this technology.
Linear Fresnel facility is similar to a PT with the advantages of low costs for structural support and reflectors, fixed fluid joints, a receiver separated from the reflector system, and long focal lengths that allow the use of flat mirrors. While in 2010 only a couple of prototypes using LF reflectors were operating, a 30 MWe LF plant built in Calasparra (Spain) started up in early 2012, and a 125 MWe commercial located in India began operating in 2014. All LF plants currently use DSG and they do not have thermal storage, which is a challenging development issue for this technology.

4.2 High-Concentration Solar Technology: The parabolic dish-Stirling engine and the central tower receiver are primarily tried for high-temperature solar thermal power plants. Stirling-dish STE plants developed for commercial applications generate power for its supply in isolated communities and villages of rural areas. Furthermore, parabolic dish has a complete two axes tracking of the concentrator aperture that would increase the amount of the incoming radiation by avoiding the cosine effect. At the focal point, the Stirling receiver absorbs solar radiation and transfers the thermal energy to the engine. The main Stirling absorbers are typically direct irradiated receivers, heat pipe receivers, and volumetric ones.
The heat pipe absorbers vaporise a liquid metal such as sodium on the absorber surface and the gas condenses on the Stirling engine heater tubes to transfer the energy to the working fluid. Heat pipe

receivers reach more uniform temperature distribution on the tubes, resulting in longer life for both the absorber and engine heater head in comparison with the direct irradiated absorber. Volumetric receivers are potentially more cost effective and reliable than the heat pipe receivers, but the design of reliable engines for large PD plants is still under development.

In central receiver systems, there are different receiver types depending on their configuration and the heat transfer medium. The configuration can be either external or cavity type. In a cavity receiver, the radiation reflected from the heliostats passes through the aperture into a box-like structure before impinging on the heat transfer surface. External receivers can be designed with a flat-plate or cylindrically shaped tubular panels.

5. OURS APPROACH:

The main purpose of our project is to increase the efficiency of solar tower by using dirty/sewerage water instead of molten salt and enhance the usage of renewable sources of energy. CST technologies is a very cheap and affordable energy source which use sunlight to produce electricity by concentrating the light on a single point. The development of renewable energy sources will ensure that the future demand of electricity is made available since the non-renewable sources of energy are depleting rapidly.

5.1 ADVANTAGES: The advantage of concentrated solar thermal technologies is that they provide a dispatchable energy supply – that is, their power output can be adjusted based on grid demand. This makes them more flexible than traditional solar PV plants.

Globally, solar thermal technology is being deployed on a large scale to provide electricity, and storage systems are also being investigated.

Abundant sunshine and plenty of open space means Australia is ideally placed to take advantage of solar thermal technologies for energy generation.

6.RESULT, CONCLUSION AND FUTURE SCOPE:

6.1 RESULT: Thus we have successfully studies about the concentrating solar thermal power plant and its applications in modern society.

6.2 CONCLUSION: Concentrating solar power technology for electricity generation is ready for the market. Various types of single- and dual purpose plants have been analysed and tested in the field. In addition, experience has been gained from the first commercial installations, in use world wide since the beginning of the 1980s. Solar thermal power plants will, within the next decade, provide a significant contribution to an efficient, economical and environmentally benign energy supply both in large-scalegrid-connected dispatchable markets and remote or modular distributed markets. Parabolic troughs, central receivers and parabolic dishes will be installed for solar/fossil hybrid and solar-only power plant operation. In parallel, decentralised process heat for industrial applications will be provided by low-cost concentrated collectors. Following a subsidised introduction phase in green markets, electricity costs will decrease from 14 to 18 Euro cents per kilowatt hour presently in Southern Europe towards 5 to 6 Euro cents per kilowatt hour in the near future at good sites in the countries of the Earth's sunbelt. After that, there will be no further additional cost in the emission reduction by CSP. This, and the vast potential for bulk electricity generation, moves the goal of longterm stabilisation of the global climate into a realistic range. Moreover, the problem of sustainable water resources and development in arid regions is addressed in an excellent way, making use of highly efficient, solar powered co-generation systems. However, during the introduction phase, strong political and financial support from the responsible authorities is still required, and many barriers must be overcome.

6.3 FUTURE SCOPE: **S**olar energy is an enormous resource that is readily available in all countries throughout the world, and all the space above the earth. Long ago, scientists calculated that an hour's worth of sunlight bathing the planet held far more energy than humans worldwide could consume in a year. We firmly believe that India should accelerate the use of all forms of renewable energy (photovoltaic, thermal solar, solar lamps, solar pumps, wind power, biomass, biogas, and hydro), and more proactively promote energy efficiency. However, in this paper, we will only focus on the use of Concentrated Solar Power (CSP) technology to meet India's future energy needs.

Concentrated solar power plants have been used in California since the 1980s. More recently, Pacific Gas & Electric has signed contracts to buy 500 megawatts of solar thermal power from two solar companies. First, Next Era Energy Resources will sell 250 megawatts of CSP generated power from the Genesis Solar Energy Project to be located in Riverside, Calif. Second, Abengoa's Mojave Solar project will supply the remaining 250 megawatts from a plant located in San Bernardino County, Calif. Subject to California Public Utility

Commission approval of the power purchase agreements, construction of these solar energy generating plants is expected to start in 2010 with operations planned to begin in 2013. Both these solar thermal power projects will contribute to meeting California's aggressive Renewable Portfolio Standard, which calls for moving away from fossil fuels to solar and other renewable energy sources that avoid pollution and greenhouse gasemissions.

In addition to California, the sunny state of Arizona has become home to the world's largest Solar Plant. Solana (which means "a sunny place" in Spanish) solar power generating station is scheduled to begin operation in 2012, harnessing Arizona's most abundant renewable energy resource – the sun. This plant (located 70 miles southwest of Phoenix) has a projected capacity of 280 megawatts, and will make use of Abengoa Solar's CSP technology.

Worldwide, Germany and Spain are leaders in solar power generation with 4,000 megawatts and 600 megawatts of installed capacity, respectively. A recently formed consortium of 12 companies, known as the Desertec Industrial Initiative (DDI), plans to spend 400 billion Euros ($557 billion) to extract solar energy from the Sahara desert. The DDI aims to deliver solar power to Europe as early as 2015 and eventually provide 15% of Europe's electricity by 2050 or earlier via power lines stretching across the desert and under the Mediterranean Sea.

The vast Rajasthan Desert is very similar to the Sahara desert in Africa, and has the potential to become the largest solar power plant in India. Due to high levels of available sunlight, CSP plants in Rajasthan could begin satisfying most of India's energy needs in just a few years. India's potential benefits from solar power are as numerous as the sands of Rajasthan desert, and include reduced dependence on fossil fuels and a cleaner environment. These benefits can be realized by installing renewable energy technologies, such as CSP, to protect the environment while diversifying energy resources and helping to lower prices. Solar power can also reduce strain on the electric grid on hot summer afternoons, when air conditioners are running, by generating electricity where it is used. India has optimal conditions to use CSP to harness solar energy from the Rajasthan Desert. However, to take advantage of this innovative technology, potential CSP plant sites must be identified and deployment accelerated. Specifically, India needs to heavily subsidize Solar and Wind Power projects just like Japan, Germany and other European nations are doing. The use of renewable energy has great potential to create more jobs in India especially in the rural areas.

REFERENCES:

[1] C. Sharma, A. Sharma, S. Mullick and T. Kandpal, "A study of the effect of design parameters on the performance of linear solar concentrator based thermal power plants in India," Renewable Energy , no. 87, pp. 666-675, 2016.

[2] X. Lu, R. Ma, C. Wang and W. Yao, "Performance analysis of a lunar based solar thermal power system with rigolith thermal storage," Energy, no. 107, pp. 227-233, 2016.

[3] A. Kassem and e. al., "A value tree for identification of evaluation criteria for solar thermal power technologies in developng countries," Sustainable Energy Technologies and Assessments, no. 16, pp. 18-32, 2016.

[4] H. Sabani, A. Tofigh, I. Kakhki and H. Bungypoor-Fard, "Design, construction and performance test of an efficient large-scale solar simulator for investigation of solar thermal collectors," Sustainable Energy Technologies and Assessments, no. 15, pp. 35-41, 2016.

[5] E. S. MAH, "Solar supported steam production for power generation in Egypt," Energy Pol, vol. 33, pp. 1251-9, 2005.

[6] B. Kelly, U. Herrmann and M. Hale, "Optimization studies for integrated solar combined cycle systems," in Preceedings of solar forum 2001 solar energy: the power to choose, Washington (DC), 2001.

[7] A. Rovira, M. Montes, F. Varila and M. Gil, "Comparison of heat transfer fluid and direct steam generation technologies for integrated solar combined cycles," Appl Therm Eng, no. 52, pp. 264-74, 2013.

[8] Y. Li and Y. Yang, "Thermodynamic analysis of novel integrated solar combined cycle," Appl Energy, no. 122, pp. 133-42, 2010.

[9] B. Alqahtani and Patino-Echeverri, "Integrated solar combined cycle power plants: Paving the way for thermal solar," Applied Energy, no. 169, pp. 927-936, 2016