International Journal of Advanced Technology in Engineering and Science
Vol. No.5, Issue No. 05, May 2017
www.ijates.com
ijates
ISSN 2348 - 7550

# DEVELOPMENT OF SOLAR THERMAL ELECTRICITY PLANTS IN INDIA

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## ABSTRACT

*Nowadays the electricity generation is big problem in the world. The major sources of electricity generation are fossil fuels. But renewable energy source provide solutions to the longstanding energy problems being faced by the world. The major problems face by developing countries. Solar energy is an important part of India not only to add new plants but also to increase energy security, address environmental concerns thus leading the massive market for renewable energy. Solar Thermal Electricity (STE) also known as Concentrating Solar Power (CSP). It is emerging renewable energy technology and can be developed as future potential option for electricity production in India. In this work, attempts have been made to summarize the accessibility, ongoing position, strategies, potential, marketing policies, major landmarks and future scope to tap the potential of solar energy in India. A worthy investment option is CSP technology having the capacity to provide for about 7% of the total electricity needs projected for the world by 2030 and 25% by 2050 (considering a lot of emphasis being paid on the energy efficiency and energy saving).*

***Keywords : Concentrated Solar Power, Solar collectors, Solar thermal electricity.***

## I. INTRODUCTION

Solar power in India is a fast-growing industry. The cumulative capacity of India's solar grid at the end of March 2016 was 6.76 giga watt (GW). As of 6 April 2017, the country's solar grid had a cumulative capacity of 12.28 GW [2]. India quadrupled its solar-generation capacity from 2,650 MW on 26 May 2014 to 12,289 MW on 10 March 2017 [2]. The country added 3.01 GW of solar capacity in 2015-2016 and 5.525 GW in 2016-2017, the highest of any year.

In January 2015 the Indian government expanded its solar plans, targeting US$100 billion in investment and 100 GW of solar capacity (including 40 GW from rooftop solar) by 2022. About India's interest in solar power, Prime Minister Narendra Modi said at the 2015 COP21 climate conference in Paris: "The world must turn to (the) sun to power our future. As the developing world lifts billions of people into prosperity, our hope for a sustainable planet rests on a bold, global initiative." India's initiative of 100 GW of solar energy by 2022 is an ambitious target, since the world’s installed solar-power capacity in 2014 was 181 GW.

In addition to its large-scale grid-connected solar PV initiative, India is developing off-grid solar power for local energy needs. The country has a poor rural electrification rate; in 2015 only 55 percent of all rural households had access to electricity, and 85 percent of rural households depended on solid fuel for cooking. Solar products

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ISSN 2348 - 7550

have increasingly helped to meet rural needs; by the end of 2015 just under one million solar lanterns were sold in the country, reducing the need for kerosene. That year, 118,700 solar home lighting systems were installed and 46,655 solar street lighting installations were provided under a national program; just over 1.4 million solar cookers were distributed in India.

In January 2016, Prime Minister Narendra Modi and French President François Hollande laid the foundation stone for the headquarters of the International Solar Alliance (ISA) in Gwal Pahari, Gurgaon. The ISA will focus on promoting and developing solar energy and solar products for countries lying wholly or partially between the Tropic of Cancer and the Tropic of Capricorn. The alliance of over 120 countries was announced at the Paris COP21 climate summit. One hope of the ISA is that wider deployment will reduce production and development costs, facilitating the increased deployment of solar technologies to poor and remote regions.

India has some of the highest solar-electricity production per watt installed, with an insolation of 1700 to 1900 kilowatt hours per kilowatt peak (kWh/KWp). On 16 May 2011, India's first solar power project (with a capacity of 5 MW) was registered under the Clean Development Mechanism. The project is in Sivagangai Village, Sivaganga district, Tamil Nadu. India saw an increase in the use of solar electricity in 2010, when 25.1 MW was added to the grid, and the trend accelerated when 468.3 MW was added in 2011. Growth has been over 3,000 MW per year

**TABLE I: ALL INDIA INSTALLED CAPACITY OF RENEWABLE SOURCES IN MW**

**(AS ON 30-06-2016) [2]**

| Small Hydro Plant | Wind Power | Bio-Power | | Solar Power | Total Capacity |
|---|---|---|---|---|---|
| | | BM Power/ Cogeneration | Waste to energy | | |
| 4333.86 | 28700 | 7856.94 | 114.08 | 9012.69 | 50017.57 |

Electricity generation from renewable is increasing importance in the context of large negative environmental externalities caused by electricity generation from fossil fuels based energy. The 33% of coal based plants generates large amounts of ash with other environmental harmful emission of gases such as carbon dioxide ($CO_2$), sulphur dioxide ($SO_2$), and nitrogen oxides ($NO_x$) [1].The power sector contributes nearly half of the country's carbon emissions. The breakup of total renewable energy resources can be shown as in Table 1.

India has achieved a total grid-connected renewable power generation capacity of 57244.23 MW till 31stMar 2017 [2], which is about 15.19 % of the total installed power generating capacity in the country and can be tabulated as in Table II and Table III.

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**TABLE II [4]**

| Programme/ Scheme wise Physical Progress in 2016-17 & cumulative upto the month of March, 2017 | | | |
|---|---|---|---|
| Sector | FY- 2016-17 | | Cumulative Achievements |
| | Target | Achievement (April - March, 2017) | (as on 31.03.2017) |
| I. GRID-INTERACTIVE POWER (CAPACITIES IN MW) | | | |
| Wind Power | 4000.00 | 5502.38 | 32279.77 |
| Solar Power | 12000.00 | 5525.98 | 12288.83 |
| Small Hydro Power | 250.00 | 105.90 | 4379.85 |
| BioPower (Biomass & Gasification and Bagasse Cogeneration) | 400.00 | 161.95 | 8181.70 |
| Waste to Power | 10.00 | 23.50 | 114.08 |
| Total | 16660.00 | 11319.71 | 57244.23 |

A capacity addition of 24,000 MW is targeted during the 12th Plan period that would take the renewable power generating capacity to nearly 54,000 MW by 2017 [4]. This thrust is believed to be sustained and it is envisaged that the renewable power capacity in the country will cross 87,000 MW by 2022.

Solar Energy and Potential [2]

With about 300 clear and sunny days in a year, the calculated solar energy incidence on India's land area is about 5000 trillion kilowatt-hours (kWh) per year (or 5 kWh/yr). The solar energy available in a year exceeds the possible energy output of all fossil fuel energy reserves in India. The daily average solar-power-plant generation capacity in India is 0.20 kWh per m2 of used land area, equivalent to 1400–1800 peak (rated) capacity operating hours in a year with available, commercially-proven technology.

Tamil Nadu

Tamil Nadu is the state with highest installed solar power capacity in India as of 21 September 2016, when Kamuthi Solar Power Project, with 648 MW capacity at a single location, was formally dedicated to the nation. With the addition of this plant, the total installed capacity in Tamil Nadu is 2,100 MW.[19] This constitutes 21% of the installed renewable energy source in the state. The other 79% is constituted by wind power. The plant is set up at Kamuthi, Ramanathapuram, in Tamil Nadu with an investment of □ 4,550 crore (US$710 million). The plant consists of 3.80 lakh foundations, 25 lakh solar modules, 27,000 tons of structure, 576 inverters, 154 transformers along with 6,000 km (3,700 mi) cables. About 8,500 personnel worked on average installing about 11 MW a day to set up the plant in the stipulated time. Tamil Nadu is now the leader in harnessing renewable energy using solar and wind energy.

Rajasthan

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Rajasthan is one of India's most solar-developed states. The total photovoltaic capacity has reached 1,784 MW by the end of March 2017. Rajasthan stands at number second in the country after Andhra Pradesh in installed capacity as on 31 March 2017. Rajasthan is also home for the 100 MW solar CSP plant at Dhirubhai Ambani Solar Park The district of Jodhpur leads Rajasthan, with installed capacity more than 1,000 MW, followed by Jaisalmer and Bikaner. Bhadala solar park of total capacity 2,255 MW is being developed in four phases. In phase first 5 projects of 60 MW capacity out of 7 projects of 75 MW capacity already commissioned by March 2016. RRECL has developed second phase of the Bhadala Solar Park of 680 MW. In this phase 380 MW capacity commissioned by March 2017 which includes 260 MW capacity commissioned by NTPC. Remaining projects in this park will commissioned by May, 2017. Development of phase III of 1,000 MW & phase IV of 500 MW has also started by joint venture companies of Government of Rajasthan with IL&FS Energy and Adani Renewable respectively.

Gujarat

Gujarat has been a leader in solar power generation in India due to several factors: a very high solar power potential, availability of wasteland, good connectivity, transmission and distribution infrastructure, and efficient utilities. These attributes are complemented by a strong political will and an investment, according to a report by the Low Emission Development Strategies Global Partnership (LEDS GP). The robust 2009 Solar Power of Gujarat policy framework, financing mechanism, and incentives, have contributed to creating an enabling a green investment climate in the state, and have led to ambitious targets for grid-connected solar power.

The State of Gujarat has commissioned Asia’s largest solar park at Charanka village. The park is already generating 2 MW solar power out of its total planned capacity of 500 MW. The park has been functioning on a multi-developers and multi-beneficiaries paradigm, and has been awarded for being the most innovative and environment-friendly project by the CII.

With a view to making Gandhinagar a solar-power city, the State government has launched a roof-top solar power generation scheme. Under this scheme, the State plans to generate 5 MW of solar power by putting solar panels on about 50 state government buildings and on 500 private buildings. The State has also a plan to emulate this project in Rajkot, Surat, Bhavnagar and Vadodara in 2012-13.

The state plans to generate solar power by putting solar panels on the Narmada canal branches. As a part of this scheme, the State has already commissioned the 1 MW Canal Solar Power Project on a branch of the Narmada Canal near the Chandrasan area of Kadi taluka, Mahesana district. This also helps by stopping 90,000 litres (24,000 US gal; 20,000 imp gal) of water/year of the Narmada river from evaporating.

Andhra Pradesh

Installed photovoltaic capacity in Andhra Pradesh is 980 MW as of 31 January 2017.[18] During 2014, APTransCo has entered into agreements with IPPs to install 619 MW. NTPC also entered into agreement in 2015 with APTransCo to install NP Kunta Ultra Mega Solar Power Project (250 MW) near Kadiri town in Anantapur district.[26][27] In April 2017, 350 MW capacity was commissioned at Kurnool Ultra Mega Solar Park by SB Energy Ltd.

Maharashtra

Sakri solar plant in Maharashtra is the biggest solar power plant in the state with 125 MW capacity. The Shri Sai Baba Sansthan Trust has the world's largest solar steam system. It was constructed at the Shirdi shrine at an estimated cost of □ 1.33 crore(US$210,000), □ 58.4 lakh(US$91,000) which was paid as a subsidy by the renewable energy ministry. The system is used to cook 50,000 meals per day for pilgrims visiting the shrine, resulting in annual savings of 100,000 kg of cooking gas and has been designed to generate steam for cooking even in the absence of electricity to run the feed water pump for circulating water in the system. The project to install and commission the system was completed in 7 months and the system has a design life of 25 years. Osmanabad region in Maharashtra has been blessed with an abundance of sunlight and is ranked the third best region in India in terms of solar insolation. A 10 MW solar power plant in Osmanabad, Maharashtra by RelyOn Solar, generates approximately 18 lakh units per MW which is the highest generation in Maharashtra of any solar power plant. This plant was commissioned in 2013 and the records of one complete year are available.

Madhya Pradesh

The Welspun Solar MP project, the largest solar power plant in the state, was set up at a cost of □ 1,100 crore (US$170 million) on 305 ha (3.05 km2) of land and will supply power at □ 8.05(13¢ US)/kWh. A 130 MW solar power plant project at Bhagwanpur in Neemuch was launched by Prime Minister Narendra Modi. This is the largest solar producer and one of the top three companies in the renewable energy sector in India.

An upcoming 750 MW solar power plant project in Madhya Pradesh in the district of Rewa will, when completed, be the world's largest solar power plant, replacing the Desert Sunlight project in California which currently has that distinction

There are following all India installed capacity ( in MW) of power stations located in different region of main land and island such as

**TABLE III:** INDIA INSTALLED CAPACITY OF POWER STATIONS LOCATED IN THE REGIONS OF MAIN LAND AND ISL [5]

**ALL INDIA INSTALLED CAPACITY (IN MW) OF POWER STATIONS**
(As on 31.03.2017)
(UTILITIES)

| Region | Ownership/ Sector | Modewise breakup | | | | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Thermal | | | | Nuclear | Hydro | RES * (MNRE) | |
| | | Coal | Gas | Diesel | Total | | | | |
| Northern Region | State | 16598.00 | 2879.20 | 0.00 | 19477.20 | 0.00 | 8543.55 | 663.56 | 28684.31 |
| | Private | 22100.83 | 558.00 | 0.00 | 22658.83 | 0.00 | 2502.00 | 10875.80 | 36036.63 |
| | Central | 12630.37 | 2344.06 | 0.00 | 14974.43 | 1620.00 | 8266.22 | 0.00 | 24860.65 |
| | **Sub Total** | **51329.20** | **5781.26** | **0.00** | **57110.46** | **1620.00** | **19311.77** | **11539.36** | **89581.59** |
| Western Region | State | 23170.00 | 2993.82 | 0.00 | 26163.82 | 0.00 | 5480.50 | 311.19 | 31955.51 |
| | Private | 31465.67 | 4676.00 | 0.00 | 36141.67 | 0.00 | 447.00 | 17993.24 | 54581.91 |
| | Central | 13657.95 | 3533.59 | 0.00 | 17191.54 | 1840.00 | 1520.00 | 0.00 | 20551.54 |
| | **Sub Total** | **68293.62** | **11203.41** | **0.00** | **79497.03** | **1840.00** | **7447.50** | **18304.43** | **107088.96** |
| Southern Region | State | 17832.50 | 791.98 | 287.88 | 18912.36 | 0.00 | 11739.03 | 512.55 | 31163.94 |
| | Private | 12124.50 | 5322.10 | 473.70 | 17920.30 | 0.00 | 0.00 | 25619.52 | 43539.82 |
| | Central | 13425.02 | 359.58 | 0.00 | 13784.60 | 3320.00 | 0.00 | 0.00 | 17104.60 |
| | **Sub Total** | **43382.02** | **6473.66** | **761.58** | **50617.26** | **3320.00** | **11739.03** | **26132.07** | **91808.36** |
| Eastern Region | State | 7025.00 | 100.00 | 0.00 | 7125.00 | 0.00 | 3537.92 | 225.11 | 10888.03 |
| | Private | 7451.38 | 0.00 | 0.00 | 7451.38 | 0.00 | 195.00 | 765.63 | 8412.00 |
| | Central | 14101.64 | 0.00 | 0.00 | 14101.64 | 0.00 | 1005.20 | 0.00 | 15106.84 |
| | **Sub Total** | **28578.02** | **100.00** | **0.00** | **28678.02** | **0.00** | **4738.12** | **990.74** | **34406.87** |
| North Eastern Region | State | 60.00 | 492.95 | 36.00 | 588.95 | 0.00 | 382.00 | 259.25 | 1230.20 |
| | Private | 0.00 | 24.50 | 0.00 | 24.50 | 0.00 | 0.00 | 21.88 | 46.38 |
| | Central | 520.02 | 1253.60 | 0.00 | 1773.62 | 0.00 | 860.00 | 0.00 | 2633.62 |
| | **Sub Total** | **580.02** | **1771.05** | **36.00** | **2387.07** | **0.00** | **1242.00** | **281.12** | **3910.19** |
| Islands | State | 0.00 | 0.00 | 40.05 | 40.05 | 0.00 | 0.00 | 5.25 | 45.30 |
| | Private | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.27 | 7.27 |
| | Central | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **Sub Total** | **0.00** | **0.00** | **40.05** | **40.05** | **0.00** | **0.00** | **12.52** | **52.57** |
| ALL INDIA | State | 64685.50 | 7257.95 | 363.93 | 72307.38 | 0.00 | 29683.00 | 1976.90 | 103967.28 |
| | Private | 73142.38 | 10580.60 | 473.70 | 84196.68 | 0.00 | 3144.00 | 55283.33 | 142624.01 |
| | Central | 54335.00 | 7490.83 | 0.00 | 61825.83 | 6780.00 | 11651.42 | 0.00 | 80257.25 |
| | **Total** | **192162.88** | **25329.38** | **837.63** | **218329.88** | **6780.00** | **44478.42** | **57260.23** | **326848.53** |

The aspiration is to ensure large-scale deployment of solar generated power for grid-connected as well as distributed and decentralized off-grid provision of commercial energy services and state-wise potential for CSP in India is shown in Table IV. The deployment road map for the technology specifies the target for Phase 1 is to have 7 million sq. m of solar collectors and subsequent targets are 15 million sq. m and 20 million sq. m for Phase 2 and Phase 3 respectively [8].

**TABLE IV:** STATE-WISE SOLAR POTENTIAL FOR CSP (IN GW) IN INDIA

| S. No. | State | CSP potential |
|---|---|---|
| 1 | Rajasthan | 1571.20 |
| 2 | Gujarat | 604.30 |
| 3 | Madhya Pradesh | - |
| 4 | Maharashtra | 2.56 |
| 5 | Andhra Pradesh | - |
| 6 | Karnataka | - |
| 7 | Jharkhand | - |
| 8 | Uttar Pradesh | 149.30 |
| 9 | Punjab | 33.12 |
| 10 | Haryana | 34.57 |
| 11 | Bihar | 125.20 |
| 12 | West Bengal | - |
| 13 | Assam | - |
| 14 | Tripura | - |
| 15 | Uttarakhand | 3.37 |
| 16 | Chandigarh | 0.28 |
| 17 | Chhattisgarh | - |
| 18 | Daman & Diu | 0.25 |
| 19 | Kerala | - |
| 20 | Lakshadweep | 0.020 |
| 21 | Manipur | - |
| 22 | Orissa | - |
| 23 | Pondicherry | - |
| 24 | Tamil Nadu | - |
| Total | | 2524.17 |

## II. CONCENTRATING SOLAR POWER (CSP) TECHNOLOGY

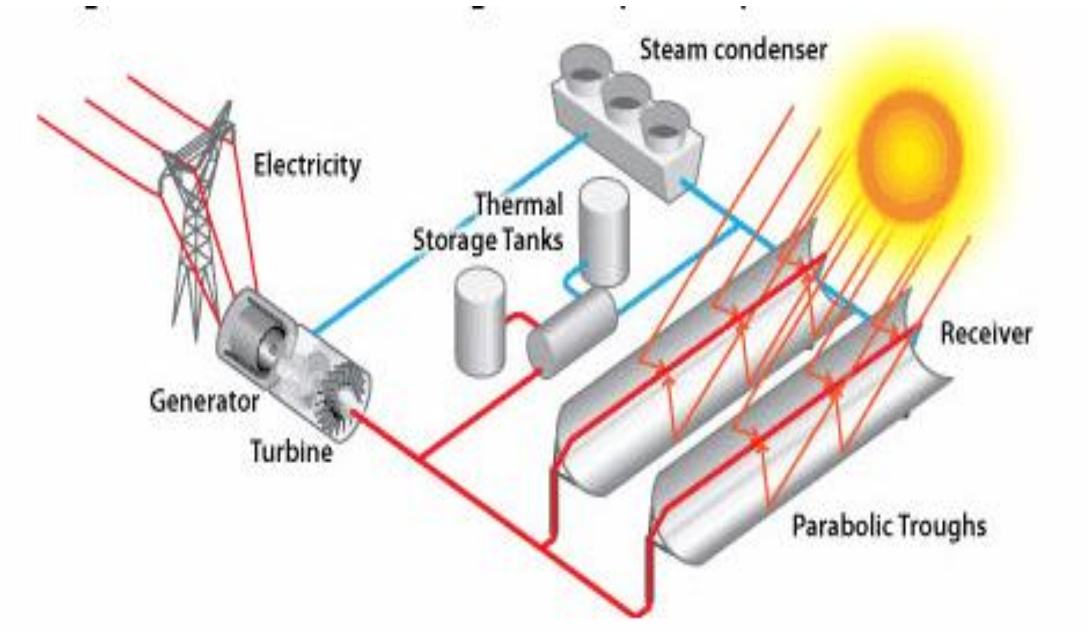
Concentrated solar power (also called concentrating solar power, concentrated solar thermal, and CSP) systems generate solar power by using mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. Electricity is generated when the concentrated light is converted to heat, which drives a heat engine (usually a steam turbine) connected to an electrical power generator or powers a thermo chemical reaction (experimental as of 2013). Heat storage in molten salts allows some solar thermal plants to continue to generate after sunset and adds value to such systems when compared to photovoltaic panels.

CSP is being commercialized and the CSP market saw about 740 megawatt (MW) of generating capacity added between 2007 and the end of 2010. More than half of this (about 478 MW) was installed during 2010, bringing the global total to 1095 MW. Spain added 400 MW in 2010, taking the global lead with a total of 632 MW, while the US ended the year with 509 MW after adding 78 MW, including two fossil–CSP hybrid plants. The Middle East is also ramping up their plans to install CSP based projects. Shams-I has been installed in Abu

Dhabi, by Masdar. The largest CSP project in the world is Ivanpah Solar Power Facility in the United States (which uses solar power tower technology) and Mojave Solar Project (which uses parabolic troughs). The global market has been dominated by parabolic-trough plants, which account for 90% of CSP plants. CSP is not to be confused with concentrator photovoltaic (CPV). In CPV, the concentrated sunlight is converted directly to electricity via the photovoltaic effect. Nowadays, Spain is considered the largest producer of electricity using the CSP technologies. Meanwhile, there are several very large solar thermal plants planned or under construction in the United States and other countries. There are four types of CSP technologies

**2.1 Parabolic Trough Collector**

A parabolic trough collector (PTC) plant consists of a group of reflectors (usually silvered acrylic) that are curved in one dimension in a parabolic shape to focus sunrays onto an absorber tube that is mounted in the focal line of the parabola. The parabolic trough is shown in figure 2.




**"Fig".1 Parabolic trough**

**2.2 Linear Fresnel reflector**

Linear Fresnel reflectors (LFR) as shown in Fig. 3, approximate the parabolic shape of the trough systems by using long rows of flat or slightly curved mirrors to reflect the sunrays onto a downward facing linear receiver. The receiver is a static structure mounted over a tower above and along the linear reflectors. The reflectors can be described as mirrors that can follow the sun on a single or dual axis regime. The principal benefit of LFR systems is that their simple design of flexibly bent mirrors and fixed receivers requires lower investment costs and facilitates direct steam production, thus diminishing the need of heat transfer fluids and heat exchangers.

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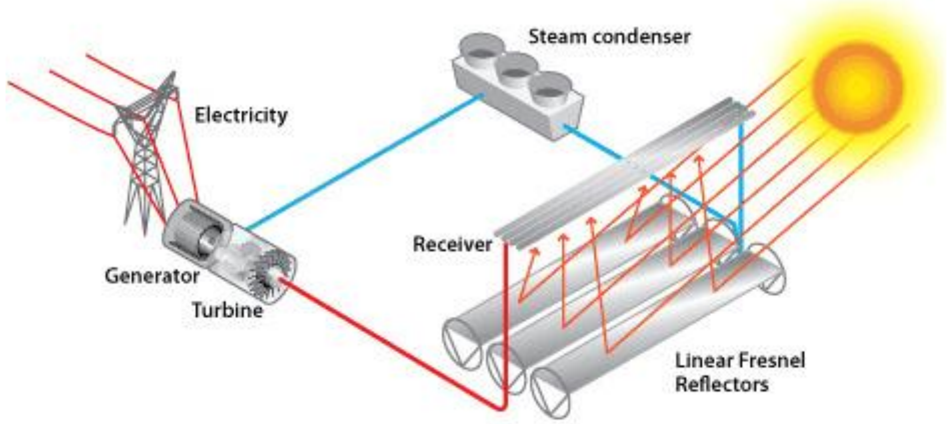
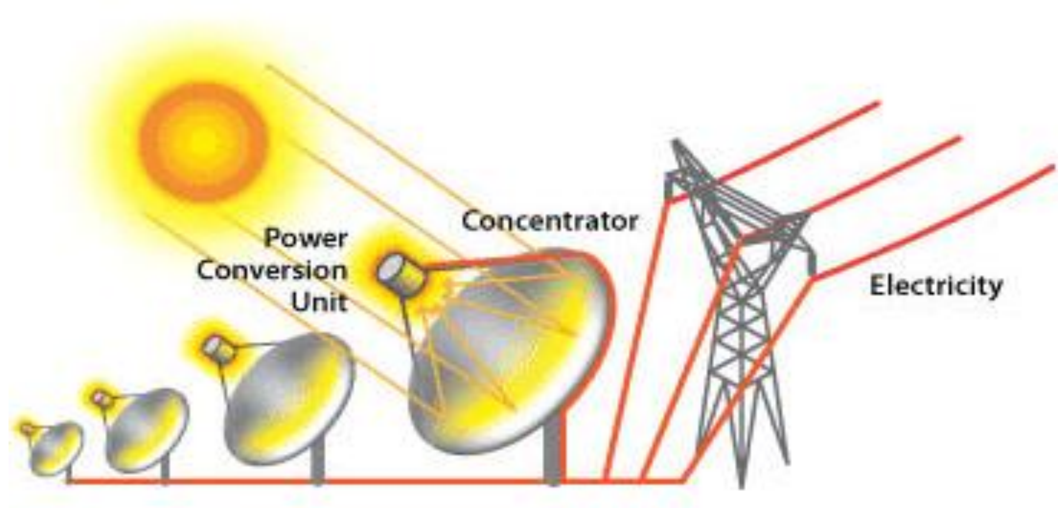
ISSN 2348 - 7550




**"Fig".2**: **Linear Frensel Power Plant**

**2.3 Parabolic Dish Systems**

Parabolic dish collectors (PDC) as shown in Fig. 4 concentrate the sunrays at a focal point supported above the middle of the dish. The complete system tracks the sun, with the dish and receiver progressing in tandem. This design removes the necessity for a HTF and for cooling water. PDCs offer the highest transformation efficiency of any CSP system. PDCs are expensive and have a low compatibility with respect of thermal storage and hybridization.

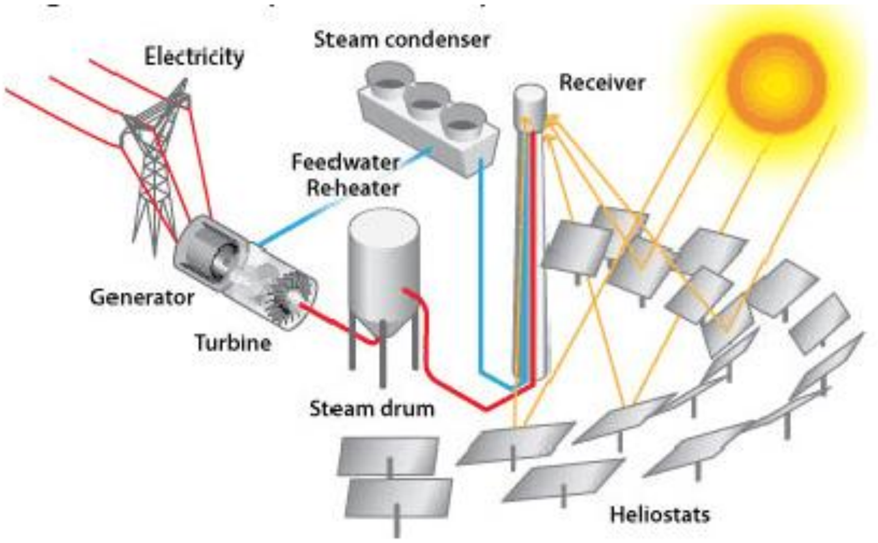



**"Fig".3 parabolic dish power plant**

**2.4 Solar power tower**

Solar power towers (SPT) as shown in Fig. 5 also known as central receiver systems (CRS), use a heliostat field collector (HFC), i.e., a field of sun tracking reflectors, called heliostats, that reflect and collects the sunrays onto a central receiver placed in the top of a fixed tower . Heliostats are flat or slightly concave mirrors that follow the sun in a two axis tracking. Heat is absorbed by a heat transfer fluid (HTF) in the central receiver, which then transfers heat to heat exchangers that power a steam Rankine power cycle.

International Journal of Advanced Technology in Engineering and Science
Vol. No.5, Issue No. 05, May 2017
www.ijates.com
ISSN 2348 - 7550




**“Fig”.4 solar power tower plant**

## III. WORLD WIDE DEVELOPMENT OF CSP

The commercial deployment of CSP plants started by 1984 in the US with the SEGS plants. The last SEGS plant was completed in 1990. From 1991 to 2005 no CSP plants were built anywhere in the world. Global installed CSP-capacity has increased nearly tenfold since 2004 and grew at an average of 50 percent per year during the last five years [10]. In 2013, worldwide installed capacity increased by 36% or nearly 0.9 giga watt (GW) to more than 3.4 GW. Spain and the United States remained the global leaders, while the numbers of countries with installed CSP were growing. There is a notable trend towards developing countries and regions with high solar radiation.

CSP is also increasingly competing with the cheaper photovoltaic solar power and with concentrator photovoltaic’s (CPV), a fast-growing technology that just like CSP is suited best for regions of high solar isolation [11,12]. In addition, a novel solar CPV/CSP hybrid system has been proposed recently [13]. The first commercial CSP plant began operating in 1986 – a 354-MW plant in California,5 although the CSP sector developed and arguably gained considerable momentum in other parts of the world only post-2005. This growth is seen mainly in Spain and in southwestern USA predominantly as a result of favorable policies like Feed-in Tariffs (FiT) and Renewable Portfolio Obligations (RPOs). The International Energy Agency’s CSP Technology Roadmap details scenarios where the global installed capacity of CSP can reach up to 1,500 GW, providing 11.3 per cent of global electricity in hybridized mode (in a combination of solar and backup fuels – fossil fuels and biomass) by 2050.6

Spain is one of the first countries in the world to introduce FiT for CSP development. The FiT was fixed at such a level that it made projects bankable and within two years over 1,000 MW was under various stages of development in the country.7 As on March 2014, Spain had an installed capacity of 2,285 MW of solar thermal power plants.8

The United States boasts of 38,000 GW of potential concentrating solar power. If these CSP plants operated at a 20 per cent capacity factor, it would generate 60.19 million kWh annually, equivalent to more than 15 times the total power generation of 3.90 million kWh in 2013.16 The Sun Belt region of the United States is one of the largest areas for CSP exploitation; its copious solar radiation in states like California, Arizona, Nevada, New Mexico, Colorado, some of Utah, and Texas could be tapped for CSP-generation plants.17 Eight of the 13 biggest planned CSP projects in the world will be located in California and Arizona.18

In Europe around 1500 MW of solar thermal power plants are either recently operating or under erection. The installed capacity in Europe is anticipated to be of 2000 MW by 2012 and an amount of greater than 30,000 MW by 2020 might be attained. Regarding a average expansion of the CSP technology, about 55% of the power is being installed in the Middle East, about 30% in Northern Africa and the prevailing 15% in Europe [6].

## IV. CSP PLANTS IN INDIA

CSP technologies are new for the India and development of CSP plants for the electricity generation is a challenging experience for industrial sector and government because demand is very large. India is yet to gain experience in building and operating solar thermal power plants on the megawatt scale. Solar energy accounts for less than 1% of the total energy produced in India [7]. While photovoltaic power plants continue to dominate in India, the Concentrated Solar Power (CSP) market is still to build, operate and sustain its first large scale solar thermal power plant in India. The majority of these projects are located in the desert state of Rajasthan [. The CSP plants are financially quite tough to compete with the coal based thermal power plants. Also, the per unit cost of generation is large as compare to thermal power plants. But some serious and successful attempts are made by the Indian government to make a clear and green future for our upcoming generation. Some plants are functioning smoothly and give support to satisfy the total demand of India with the other renewable resources

―ACME Solar Tower‖ project is the oldest operational CSP plant in India, it started operation in April, 2011 of capacity 2.5 MW; it is situated in Bikaner, Rajasthan. The technology used for electricity generation is solar power tower technology. This plant has the 14,280 numbers of heliostats, which cover the 16,222 m2 heliostat Solar-Field aperture area in solar plant, 1.136 m2 is the aperture area covered by each heliostat. Height of the solar tower is 46 m and water/steam is used as heat transfer fluid (HTF). This plant working on steam Rankine cycle having power cycle pressure of 60 bars. Working fluid enters in receiver at initial temperature 218oC and leaves at 440oC as outlet temperature. Cooling is very important in high temperature regions so wet cooling is used for the cooling towers and there is no thermal storage in this plant. ACME group is the 100% owner of the plant.

In 2010, IIT Bombay, create a test facility which would help in gaining skill in fabrication, operation and maintenance of large capacity solar thermal power plants. This provision would also assist in facilitating research development in the solar industry in India. This project was named ‗National Solar Thermal Power Testing, Simulation and Research Facility'. The purpose of the project was to commission an expected

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ISSN 2348 - 7550

combined capacity of 5 MWth, distribute it to the national grid and also to act as a facility for component testing . The 5 MWth power was divided into two power plants of different technologies: Parabolic trough and linear Fresnel reflector technique. The 3MWth parabolic trough solar plant was built by Abengoa. Abengoa (MCE: ABG.B) applies innovative technology solutions for sustainability in the energy and environment sections producing electricity from inexhaustible resources, transforming biomass into biofuels and yielding drinking water from sea water. The solar thermal parabolic trough field of capacity 3 MWth built by Abengoa, is the first parabolic trough power plant in India. Therminol VP-1 is the heat transfer fluid used which has an operating range of 12 - 400 degree Celsius. The operating system of the solar field is based on a hierarchical architecture of three levels. The plant is provided with controllers to track the position of the sun on real time basis and optimize the energy consumption. The plant does not liberate any carbon dioxide into the surrounding. The parabolic trough solar collector plant has been provided by Abengoa, and the power block and the Heat Transfer Fluid (HTF) system have been supplied by IIT Bombay. The solar plant comprises of three loops with parabolic troughs altogether of about 1,500 meters in length and crossing an area of 8,000 square meters. The solar field arrangement of three loops of four collectors includes 12 steel structures of 10 modules, 3,360. There are following projects which are currently in operation or under construction such as [3]:

| S.No. | Project Name | Location | Technology | Heat-Transfer Fluid Type | Turbine Capacity (MW) | Thermal Storage | Status, Start year |
|---|---|---|---|---|---|---|---|
| 1. | Abhijeet Solar Project | Rajasthan, (Jaisalmer) | Parabolic trough | Therminol VP-1 | Net: 50.0 Gross: 50.0 | None | Operational, 2015 |
| 2. | ACME Solar Tower | Bikaner (Rajasthan) | Power tower | Water/Steam | Net: 2.5 Gross: 2.5 | None | Operational, 2011 |
| 3. | Dadri IISC Plant | Dadri (U.P.).) | Linear Fresnel reflector | Water/Steam | Gross:14.0 | None | Under construction |
| 4. | Dhursar | Dhursar (Rajasthan) | Linear Fresnel reflector | - | Net: 125.0 Gross: 125.0 | None | Operational, 2014 |
| 5. | Diwakar | Askandra (Rajasthan) | Parabolic trough | Synthetic Oil | Net: 100.0 Gross: 100.0 | 4 hours | Operational, 2013 |
| 6. | Godawari Solar Project | Nokh (Rajasthan) | Parabolic trough | Dowtherm A | Net: 50.0 Gross: 50.0 | None | Operational, 2013 |
| 7. | Gujarat Solar One | Kutch (Gujarat) | Parabolic trough | Diphyl | Net: 25.0 Gross: 28.0 | 9 hours | Operational, 2014 |
| 8. | KVK Energy Solar Project | Askandra (Rajasthan) | Parabolic trough | Synthetic Oil | Net: 100.0 Gross: 100.0 | 4 hours | Operational, 2013 |
| 9. | Megha Solar Plant | Anantapur (Andhra Pradesh) | Parabolic trough | Synthetic Oil | Net: 50.0 Gross: 50.0 | None | Operational, 2014 |
| 10. | NSFT | Gurgaon | Parabolic trough | Water/Steam | Net: 1.0 Gross: 1.0 | None | Operational, 2012 |

## V. ENCOURAGING FACTORS FOR CSP PLANTS IN INDIA

There are many factors that encourage the future development of CSP plants in India. These are as follows [9]:

- **Renewable source**: Solar power comes from sun which is a renewable source of energy, so no fuel/less fuel requirement for generation.
- **Environment friendly**: Solar power is beneficial to the environment and reducing the global warming by reduces the emission of greenhouse gas. Carbon free except for production and transportation.
- **Free energy:** Solar energy is available in free of cost.
- **Best option for rural locations:** Rural areas which are very far from generating station where there is no easy way to supply electricity by other means, for that cases it‘s an easy way to supply electricity.
- **Reduce dependency:** Solar power will reduce the dependency on fossil fuels and give us time to encounter the problem of fast depletion of resources.
- **Beneficial to economy:** We have to pay for once after that there is very little cost or no cost in using the sunlight.
- **Unlimited amount of energy:** The sun‘s energy is readily available to harness for energy production.
- **Carbon credits:** Carbon credits are the extra benefits which reduced the cost of generation.
- **Reliability:** Can utilize thermal storage to better match supply with demand.
- **Integrated with traditional thermal power plants:** CSP plants can be integrated with conventional thermal power plants due to which use of fossil fuels decrease.
- **Large desert area:** Availability of large dessert, unproductive land areas in Rajasthan and Northern Gujarat are suitable for CSP plants.

## VI. CONSTRAINTS FOR CSP PLANTS IN INDIA

We have identified various constraints to implement CSP plants installations in India from the literature reviews and expert opinions. After reviewing the literature for identify the constraints to implements in India. Although, the literature was not relevant in Indian context, we have taken the literature from some others developed/ developing countries. We assumed similar situation for India also. After reviewing the literature constraints identified are as follows [9]

- High initial capital cost
- High pay-back period
- Less efficiency
- Need for backup or thermal storage
- Absence of solar radiation data
- Lack of consumer awareness to technology
- Absence of skilled people and training institutes
- Lack of financing mechanism
- Lack of sufficient market base
- Insufficient local infrastructure

- Lack of political commitment
- Lack of adequate government policies
- Lack of research & development work
- Low energy density
- Manufacturing processes seldom causes pollution

## VII. CONCLUSION AND RECOMMENDATIONS

In this research study, an attempt has been made to identify and analyses the factors that encourages the development of CSP technologies implementation in India. We identified the eleven factors those encourage the implementation of CSP plants in India and we also found that there are many constraints which restrict the development of CSP plants in India. One important finding is that if we use the CSP plants and combined these plants with than a large amount of fossil fuel and carbon emission is reduced, by which our dependency on other countries for fossil fuels is decreases. In light of the necessity to tackle climate change, energy produced from renewable sources has gained much importance. Solar thermal technologies with promising low carbon emission plays an important role in global energy supply. CSP projects have the potential to be competitive with conventional power generation sources. The establishment of feed-in tariffs and other inducements, approving dynamic government policies, and the support of industry, researchers and other stakeholders plays crucial role in the development of CSP technology and its deployment for attaining energy goals as shown in figure 6. Renewable energy is the future of India‘s economy and CSP plants play a major role in it.

The recommendations are as follows:

- In spite of the fact that each of the three primary types of storage media (sensible, latent, thermo chemical) have the potential to make CSP plants more profitable, more research is still needed to improve the thermal performance and economics of these systems.
- Due to scarcity of water in Rajasthan Parabolic dish / Engine system is a suitable option.
- As on April 2017, Total installed capacity of thermal power in India is 220893.2 MW which is 67.1 % of total installed capacity (329200 MW) of India [2], if we trying to combine these thermal power plants with Solar thermal power plants then a huge amount of fossil fuel are saved and we get a pollution free clean energy.
- Various CSP techniques like Heliostat, parabolic dish system and solar chimney are not used up till now in India on large scale, for that government should try these technologies also.

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