Improving Generation of Solar Power in India

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ABSTRACT*: Global energy demand is increasing and traditional sources of energy such as coal and petroleum are depleting, and renewable resources must play a crucial role in the future. It is imperative to develop renewable and sustainable energy solutions to avert the imminent climate crisis. A worthy investment choice is to concentrate solar power (CSP) technology capable of providing about 10% of the world's total electricity needs expected by 2030 and 25% by 2050 (considering a high-energy, high-efficiency scenario). The numerous available concentrators have been discussed in the present analysis. Countries around the world have recognized the potential for CSP, and multiple plants are being planned and built with government incentives. In India the Rajasthan and Gujarat states have the potential for widespread use of CSP technology to harness the solar power. The Indian Government's launch of The Jawaharlal Nehru National Solar Mission (JNNSM) and its initiatives, complemented by state solar policies passed by the states of Rajasthan and Gujarat, would go a long way in establishing CSP to supply a segment of India's upcoming energy needs.

***KEYWORDS*: Solar, CSP, India, Renewable energy, Photo voltaic cell, Global warming, Fossil foil.**

INTRODUCTION

Energy sources will play a significant role in the future of the planet in light of the increasingly growing global demand for electricity. World primary energy consumption figures are that fossil fuels provide 80 per cent of the supply. Considering different scenarios, it is predicted that primary energy usage will increase between 32 and 84 per cent by 2050. Nevertheless, the reserves of fossil fuels are rapidly decreasing and there is an increasing need to significantly reduce greenhouse gasses and other contaminants in the light of the severe climate problem that will have to be addressed if developed countries do not in the foreseeable future restrict carbon emissions from their power sector. Therefore, the development of low-carbon technologies and their global adoption is an urgent priority that has drawn attention to the new and renewable energy sources that offer great potential for meeting the energy needs of mankind with negligible carbon emissions.

Like fossil fuels, renewable energy sources are inexhaustible and more widespread across the Earth's surface, it has been stated that large hydro, bioenergy, geothermal resources and CSPs provide comparable levels of firm ability to conventional fossil fuel-based plants, while sources such as solar Photo Voltaic (PV) technologies, wind, and likely small hydro and wave energy resources in conventional fossil fuel-based plants The 2010 Energy Development Perspective notes that renewables could account for 48 per cent of power generation in the BLUE Map scenario, which sets the goal of halving global energy-related carbon emissions by 2050 [1].

The energy from the sun, which amounts to almost 4000 trillion kWh daily in the form of electromagnetic radiation, exceeds mankind's total primary energy supply, accounting for 10,000-fold annual global energy consumption, which is far more than other energy sources available at ground level, such as geothermal or tidal energy, nuclear power and fossil fuel burning. Climate sustainability, economic development, job creation, fuel diversity and rapid deployment, as well as the global technology transfer and innovation potential are some of the compelling benefits of solar power. The technology has immense potential where scenarios are projected to contribute between 12 per cent and up to 25 per cent of global power by 2050. Renewable energy production [2], led by wind and solar, hit an all-time high in 2008, and was maintained following the economic downturn.

The commercial energy consumption in India has risen rapidly, keeping up with a high rate of economic development. The installed power capacity in India as of September 2010 is about 165 GW. India is heavily dependent on coal for energy production, as is evident from shares of various sources where coal was the source of 53.4% of the energy produced, followed by hydropower – 22.6%, gas – 10.6%, nuclear – 2.8%, oil – 0.6%, and renewable energy – 10%. With regard to the renewable capacity built globally, China now ranks second and fifth over India. Considering India's increasingly growing demand for per capita electricity, it was realized that India's sustainable development called for energy sector growth with efficient management and a proper mix of available renewable and non-renewable energy sources. On 30 June 2008, the Indian Government announced a new policy direction through its National Action Plan on Climate Change (NAPCC), which proposes significant R&D and infrastructure expenditure to increase the share of solar energy in the total energy mix. The Jawaharlal Nehru National Solar Mission (JNNSM), one of eight NAPCC National Missions launched on 11 January 2009 with USD930 million funding, is an ambitious project to make India a global leader in solar power producing 20,000 MW of solar power by 2022.

There are two commonly used technologies in the use of solar energy to generate electricity – PV and CSP, where CSP appears to be leading PV for power generation on a utility scale, partially due to its maturity and relative cost. CSP, a commercially available technology, uses direct sunlight and mirrors to boil water as a heat source for steam generation and power traditional steam turbines, instead of fossil fuel. The first of CSP's two advantages over PV is that CSP systems can be installed with an integrated thermal energy storage network, thereby having the capacity to produce electricity during the evening hours (usually a peak demand period). Second, solar thermal plants can be fitted with auxiliary burners to generate electricity when there is no sunlight available. Other considerations include the thermodynamic efficiency and energy costs per unit area. Not only does the conversion of solar heat into electricity lead to an efficiency of approximately 42 per cent compared to 15 per cent of PV systems, but also, in order to generate the same energy, the solar collector plant needs a site four times smaller than PV, thus allowing energy production at a price four times lower than PV. According to recent estimates, CSP could generate as much as 7 percent of the world's estimated global electricity needs by 2030 and 25 percent by 2050 (considering a high energy-saving, high energy-efficiency scenario).

The world solar resource

Potential CSP sites worldwide are defined using Direct Normal Irradiance (DNI) Global Distribution. In the sunniest countries, the area of the planet with more solar radiation, known as the "Sun Belt," with vast areas with particularly high solar radiation and well suited to large amounts of solar systems, it is expected that CSP will become a competitive source of bulk power in peak and intermediate loads by 2020 and base-load power by 2025–2030. Potential sites have a solar radiation efficiency cap set at a DNI of at least 2000 kWh per sq. M per year and new proposals for that level of irradiance are being developed commercially. The first commercial plants designed by Luz International Ltd. began to operate in Mojave Desert, but a decline in fossil fuel prices led to the weakening of the policy system that enabled CSP's development.

In 2006, the sector re-emerged in Spain and the United States in reaction to government initiatives such as feed-in tariffs and policy reforms promoting solar power generation. In September 2010 the California Energy Commission approved four solar thermal power plants with a total planned capacity of around 1000 MW for construction and operation at the Blythe location in California, leading to the licensing of nearly 3000 MW of large-scale solar power It is estimated that about 118 GW will be deployed by 2030 and 1504 GW by 2050 for the US. In Europe approximately 1500 MW of solar thermal power plants are either running recently or under construction. The installed capacity in Europe is expected to be 2000 MW by 2012 and could hit an sum of over 30 000 MW by 2020. With a reasonable growth of the CSP technology, it is anticipated that 83 GW will be deployed in this area by 2030 and 342 GW by 2050, approximately 55 percent of this power will be deployed in the Middle East, 30 percent in North Africa and the remaining 15 percent in Europe. In Spain, 81 MW are in service, 839 MW are under construction and 10,813 MW are under production, which exceeds projections from the 2005–2010 Spanish Renewable Energy Plan.

Potential for solar energy in India

India is located in the world's sunniest regions and the Indian Meteorological Department has collected data showing that there are 250–300 clear and sunny days in a year. In India, there is a high potential for solar energy, provided that both technology routes for transforming solar radiation into heat and electricity are viable for harnessing solar thermal and solar photovoltaic photovoltaics providing enormous scalability. Approximately 5000 trillion kWh of energy per year is incident over India's land area with the majority of sections receiving 4–7 kWh every sq.m per day. Given the current level of production, 1% of the land area is adequate to meet India's electricity needs by 2031.

According to the Ministry of New and Renewable Energy (MNRE), in Rajasthan and northern Gujarat, the maximum annual global radiation is provided. The data and maps of solar resources established for Northwestern India identify the potential for widespread application of flat-plate and concentration of solar collectors in this area. The Rajasthan state receives approximately 5.5–6.8 kWh of solar radiation per sq. M twice. It is projected that solar power plant with a capacity of about 35–50 MW may be installed on one sq. Kilometer of land area as stated in a recent MNRE press release.

LITERATURE REVIEW

This chapter introduces Concentrating Solar Power (CSP), described as power generated in CSP systems that uses solar concentrators to convert solar energy into heat and then convert the heat created to power using Rankine, Brayton and Stirling cycles based heat engine. This chapter discusses the key technologies of solar concentration and solar energy resources based on sun characteristics and solar radiation intensity. This then discusses the details of the key integrated power plant technologies for transforming solar energy resources into electricity and the technologies used for storing solar thermal energy. This chapter summarizes the applications of the Brayton Cycle of supercritical CO2 in concentration of solar power plants. The design and operation of CSP plants is evaluated to highlight the power cycle specifications and the beneficial characteristics for solar-thermal application. At temperatures applicable to CSP applications, the sCO2 Brayton cycle provides the promise of higher cycle efficiency than superheated or supercritical steam cycles. Additionally, Brayton cycle systems that use sCO2 are predicted to have lower weight and volume, lower thermal mass, and less complex power blocks compared to Rankine cycles due to higher fluid density and simpler cycle design [3]. The use of these high-tech devices in a wide field of practice embolds performance-level improvement. This work compiles the current literature to include a comprehensive overview of the development of Concentrated

Solar Power-CSP-mechanization and worldwide implementation. The goal of this study is to provide thematic documentation as a basis for approaching the idea of a solar polygeneration system and the possibilities for its implementation. It also aims to underline the CSP's position in the current and future world energy system. This paper provides a study of methodologies for the design of thermal energy storage systems and the considerations to be considered for concentration of solar power (CSP) plants at different hierarchical levels.

Storage of thermal energy is a key component of an electric power plant to enhance its dispatch ability. There have been many storage media reports, there are not many that concentrate on the architecture of the storage device along with its integration into the power plant. This paper explores the designs of the thermal energy storage system discussed in the literature, along with thermal and exergy performance analyzes of various integrated thermal energy storage systems in the power plant [4]. This paper focuses on the latest technologies and innovations in solar thermal technology, and offers a study of solar collectors and thermal energy storage systems. Various types of solar collectors are investigated and debated, including both non-concentrating collectors (lower temperature applications) and concentrated collectors (high temperature applications). These are studied in terms of optical optimization, reduction of heat loss, enhancement of heat recovery and various mechanisms of sun-tracking. Often checked and addressed are different types of thermal energy storage systems including sensible heat storage, latent heat storage, chemical storage, and cascaded storage [5].

The solar calculations showed that the total annual Direct Normal Irradiance (DNI) on the site being measured amounts to 1132 kWh / m2. The performance of thermal collectors, which depends on climatic conditions such as solar insolation, ambient temperature, receiver temperature and heat loss, ranges from 60 to 80%. The cost effectiveness when combining the tested Fresnel solar collection system with a solar multiple of 1.0 with a commercial thermal desalination plant is compared to one run entirely on fossil fuel [6]. This study addresses the current state of heat transfer fluid, which is one of the key components in the concentration of solar power systems for storing and transmitting thermal energy. Different types of heat transfer fluids including air, water / steam, thermal oils, organic fluids, molten salts, and liquid metals are studied in detail, especially with regard to melting temperature, thermal stability limit, and corrosion problems. The standard piping and tube materials for heat transfer fluids are stainless steels and nickel based alloys. Stability of the stainless steels and alloys is very critical for the durability of concentrated solar power systems when in contact with heat transfer fluids. In terms of corrosion rates, the corrosion properties of stainless steels and nickel-based alloys in different heat transfer fluids are debated [7]. The topics covered include absorber materials for solar thermal receivers, design optimization by integrated techno-economic modeling, optimization of heliostat sizes, heat flux and temperature measurement technologies, concentration of solar heating and cooling for industrial processes, and residential and industrial residential chemicals. With its esteemed editors and an international team of experts, Concentrating Solar Power Technology is an important guide for all those involved or interested in designing, producing, creating, optimizing and implementing CSP technology, including renewable energy engineers and consultants, environmental departments, manufacturers of solar thermal equipment, research [8].

METHOD

CSP techniques often use direct sunlight, absorbing it many times in the aim of solar thermal absorption systems to achieve higher energy densities – and therefore higher temperatures as the light is absorbed by a material surface. Instead heat is used to run a traditional power cycle, e.g. from a steam or gas turbine or a sterling engine, which drives a generator. A typical solar thermal power plant therefore includes the following components: collector array & solar tracking system, absorber, heat transfer fluid, heat transfer mechanisms, electromechanical devices and, if desired, some form of energy storage system and/or solar thermal power plant hybridization to meet low and non-solar needs.

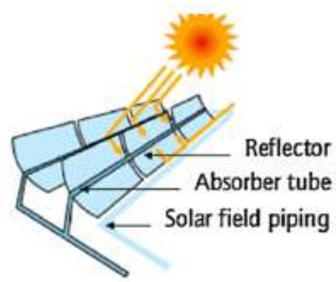

FIGURE 1: Parabolic trough

Parabolic trough

In each parabolic trough there are a series of curved mirrors used to concentrate sunlight on thermally efficient receiver tubes mounted in the focal line of the trough through which synthetic oil is used as a heat transfer medium, heated to approximately 400 μC by the focused sun's rays (see Fig. 1). Most of these solar collectors' parallel rows usually aligned north to south, spaning around the solar field. The oil transfers heat from the collector pipes to heat exchangers, where it preheats, evaporates and then overheats. The superheated steam powers a turbine that drives a generator to generate electricity, and after cooling and condensing, the water returns to the heat exchangers. With the sunlight concentrated approximately 70–100 times, the operating temperatures reached are within the range of 350–550 C. The annual solar energy production is estimated at 15%. The option for incorporating a parabolic trough solar field into a steam turbine power plant is the generation of steam in the solar field called the technology of direct steam production. The first parabolic trough systems near Cairo (Egypt) were built in 1912. The feasibility analysis of the construction of parabolic solar thermal power plants in China's Inner Mongolia, carried out in a report, resulted in the power plant being able to operate with its full commercial volume and produce electricity to grid under state policy support.

Solar tower

In solar thermal power tower plants, large mirrored collectors called heliostats monitor incident sunrays. In a recent study data were provided on the proper distribution and maintenance strategy of the heliostats around the tower. Such heliostats focus the energy flux on the receiver that is mounted on top of a tower (see Fig. 2) and where energy is transferred to a working thermal fluid at high temperatures above 1500 C, to be used for subsequent electricity production as in the case of parabolic troughs. The average solar flux affecting the receiver has values ranging from 200 to 1000 kW per sq. M which makes working temperatures easier. In a central recipient field, heliostats represent the largest single investment of capital. The solar tower plant's capacity ranges from 10 to 200 MW with annual solar to 20–35 percent electrical output. For large plants with a proposed capacity of 100–200 MW, heat transfer media like water / steam, molten salts, liquid sodium, and air was identified. Solar One, which operated in the USA from 1982 to 1988 and became the world's largest power tower plant with a power output of 10 MWe in the summer, has proven feasible for large-scale power generation with power towers.

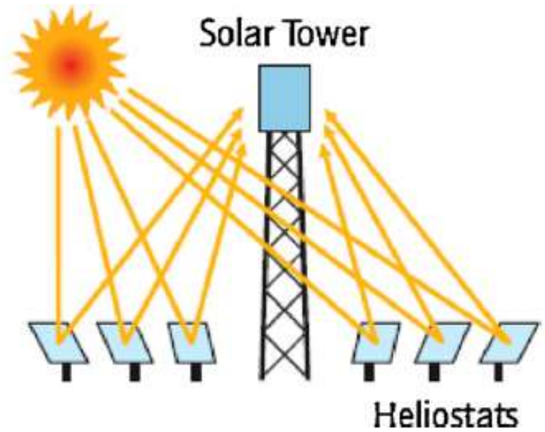

FIGURE 2: Solar Towers.

Parabolic dish

The parabolic platter reflector is a point-focus collector that monitors the sun in two directions and concentrates solar energy on the receiver at the focal point of the platter. Once the centered beam occurs on the receiver, the fluid or gas (air) in the receiver is heated to around 750 μC. A heat engine / generator unit is connected to the receiver-a stirling engine or a gas turbine that is used to transform the energy contained in the fluid or gas into electricity. Parabolic dish plant capacities are in the range 0.01–0.4 MW. Müller-Steinhagen and Trieb estimated the annual solar energy output to be between 25 and 30%. The optical efficiency of the dish is significantly higher than that of the trough or tower systems because the mirror is always pointing directly to the sun, whereas the trough and tower suffer a reduction in the projected area, called cosine losses, due to frequent low incidence angles.

CONCLUSION

Given the need to tackle climate change, renewable energy sources are becoming increasingly important. Solar thermal technologies with promising low emissions of carbon will play a major role in future global energy supply. As of the beginning of 2010, the global stock of CSP plants exceeded capacity of 1 GW. It is estimated that a range of projects being built in countries like the USA, Spain, India, Egypt, Morocco and Mexico will reach 15 GW. Several countries, including India, exploited the opportunity to harness the solar resource. In the near future CSP ventures have the ability to compete with traditional sources of power generation. World policymakers are regularly announcing opportunities for solar thermal power plant construction and setting policy structure. MNRE, Government of India launching The JNNSM is the first step in promoting and establishing solar energy as a viable alternative to conventional sources. The establishment of feed-in tariffs and other incentives, the implementation of competitive government policies and the cooperation of industry, researchers and other stakeholders would play a crucial role in the growth and deployment of CSP technology to achieve future energy goals.

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