

Cost reduction potential of parabolic trough based concentrating solar power plants in India



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ABSTRACT

In this paper, we estimate the cost reduction potential of parabolic trough based concentrated solar Power systems in India and consequently their implications for levelized cost of electricity. Using the past as well as envisaged global cumulative diffusion of CSP systems and the learning rates reported in the literature, the expected capital cost of parabolic trough based CSP systems in India has been estimated. Present capital cost of parabolic trough based CSP plant in India has been taken as US \$2540/kW. Local manufacturing of CSP components and consequently reduced logistics is expected to reduce the capital cost by 14% and 8% respectively. A learning rate of 10% for the global cumulative diffusion in the base case scenario is expected to reduce capital cost to 49% of the present cost by the end of 2050. Present LCOE of US \$151/MWh of CSP plant in India is expected to reduce to US \$76/MWh by the end of 2050. Provision of 6 hour thermal storage is expected to reduce LCOE of CSP plant in India by 18% as compared to LCOE of CSP plant without storage. Analysis for different learning rates (5%, 10% and 15%) for CSP plant and different discount rates (6%, 8% and 10%) has also been undertaken and results obtained are presented.

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Introduction

Concentrated solar power (CSP) is an option for generation of electricity using solar energy. Worldwide, around 4815 MW capacity plants are operational up to December 2016 (SolarPACES, 2017) signifying the importance of CSP technology for providing electricity in a sustainable manner without adversely affecting the environment. Four different solar concentrator technologies, namely the parabolic trough, central tower receiver, linear Fresnel reflector and parabolic dish have been developed for power generation. A schematic of parabolic trough based CSP plant is presented in Fig. 1. A solar collector field redirects the beam component of solar radiation incident on its aperture on to a receiver that absorbs the concentrated flux falling on its surface. The incident photons thus converted into heat that is extracted and transferred to a heat transfer fluid. The hot fluid then exchanges heat in a steam generator where water is converted into steam that is expanded in a turbine and power is generated.

The levelized cost of electricity (LCOE) of CSP plants is relatively higher than several of the competing renewable energy based electricity generation options such as solar photovoltaic power. This is primarily due to the fact that there has been considerable advancements in photovoltaic technology leading to a drastic reduction in cost per peak

Watt of solar cells. As a consequence, the LCOE of PV plants has reduced considerably in last 3–4 years, thus making the solar photovoltaics as the preferred option for solar power generation.

Despite the fact that presently capital cost of CSP systems is considerably higher than the capital cost of solar photovoltaic systems, the interest in CSP technology is growing for several reasons that include (i) possibility of including relatively inexpensive thermal storage component in CSP systems so as to facilitate better dispatch ability, (ii) relatively higher conversion efficiency (solar to electric) as compared to that normally achievable with existing commercial photovoltaic plants and (iii) relatively higher capacity utilization factor (23% to 28%) of CSP systems (Purohit et al., 2013) as compared to photovoltaic systems (12% to 18%). CSP systems are generally tracked whereas PV systems are rarely tracked, resulting in higher capacity utilization factor.

Several studies (ESMAP, 2012; IRENA, 2012; Sundaray and Kandpal, 2013; IEA, 2014; Sharma et al., 2017) have reported that the cost of CSP technology can be reduced in the future. The measures that can contribute towards such a cost reduction of CSP technology include, technological advancements in the components (concentrators, receiver tubes, heat transfer fluid, etc.) leading to efficiency improvements, local manufacturing of CSP components and by experience and/or enhanced learning about the CSP plants in operation.

In view of the above and the fact that the present capital cost of a CSP system is significantly higher than the capital cost of photovoltaic based systems, it would be useful to study different cost reduction possibilities

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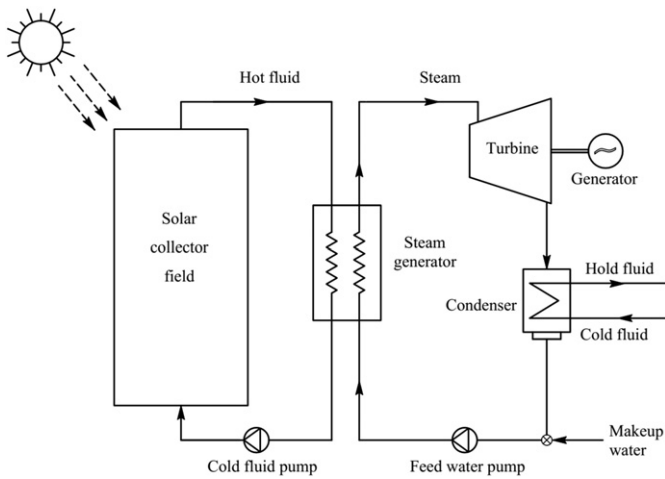


Fig. 1. Schematic of parabolic trough based CSP plant.

of CSP systems so as to make their LCOE competitive with that of photovoltaic systems.

A preliminary attempt has been made in this paper to review the cost reduction possibilities of parabolic trough based CSP systems in India and their implications for levelized cost of electricity. Parabolic trough based CSP plants based on simple Rankine cycle and without the use of any supplementary fossil fuel (such as natural gas) have been considered for the analysis. Since the modelling of cost reduction possibilities is often related to the cumulative diffusion of the technology (Neij, 2008; Moro and Duarte, 2012; Huenteler et al., 2014), a brief review of the status of CSP technology and the time trend of the installed capacity has been presented. The current status of CSP technology in India has also been presented. A summary of different possibilities of cost reduction in parabolic trough based CSP plants (with primary focus on India) is then presented. Finally, the expected cost of parabolic trough based CSP plants in the future has been estimated and the same has been used to estimate the likely values of the levelized cost of electricity delivered by parabolic trough based CSP plants in India.

Global status of CSP plants

The majority of the plants installed worldwide are in the United States of America (USA) and Spain with a small capacity installed in China, Australia, Algeria, South Africa and India. Despite the fact that plants installed in mid 80s in the USA were successful as CSP technology, no new CSP plants were commissioned until 2006. Significant capacity addition (Fig. 2) has however been made after 2006 (SolarPACES, 2017). By the end of December 2016, CSP plants of cumulative capacity of 4815 MW were operational across the world, 1260 MW capacity

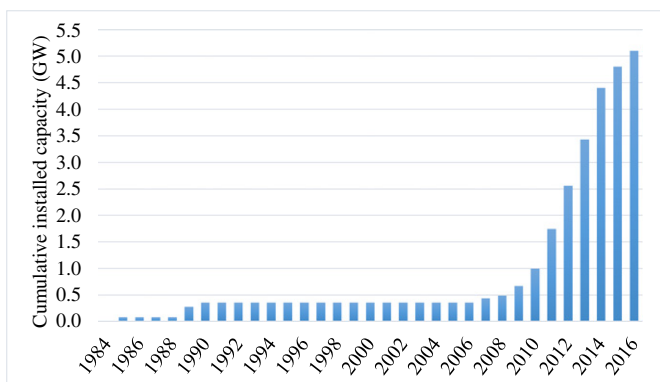


Fig. 2. Cumulative installed capacity of CSP plants worldwide (SolarPACES, 2017).

plants were under construction and 2709 MW capacity plants were in the development stage (SolarPACES, 2017).

Details of few operational CSP plants in United States and Spain are presented in Table 1 (SolarPACES, 2017). There is significant variation in the reported capital cost of the CSP plants. The capital cost is varying from US \$3540/kW to US \$7060/kW.

The average LCOE of CSP based systems by region varies from a low of US \$0.20/kWh in Asia to a high of US \$0.25/kWh in Europe with the LCOE of individual projects varying significantly depending on location and solar resource (IRENA, 2012). However, as costs are falling, recent projects are being built with LCOE of US \$0.17/kWh and power purchase agreements are being signed at even lower values where low cost financing is available.

Average capital cost projections for all types of CSP plants without storage and with 6 h of storage are presented in Fig. 3 (IEA, 2014). As can be seen from Fig. 3, projected capital cost of CSP plants is expected to be US \$2300/kW (without storage) to US \$3100/kW (with provision for 6 h of thermal storage) by the year 2050. As a consequence of reduction in capital cost and also of improved performance, a significant lowering in the LCOE (Fig. 4) is expected.

Status of CSP plants in India

With the launch of Jawaharlal Nehru National Solar Mission (JNNSM) in 2010, activities towards large scale dissemination of CSP plants in India has gathered considerable momentum. Several research groups have undertaken research and development activities on CSP plants in recent years (CSTEP, 2012; Reddy et al., 2012; Desai et al., 2014).

A brief summary of operational CSP plants and plants under construction is presented in Table 2 (SolarPACES, 2017). As shown in Table 2, CSP plants of cumulative capacity 225 MW are operational and 292 MW capacity plants are under construction. Comparing reported capital cost of operational CSP plants in United States and Spain (Table 1) to the reported capital cost of few operational CSP plants in India (US \$2520/kW to US \$2540/kW) in Table 2, It is found that there is significant variation in the reported capital cost. To a large extent, the difference in the reported values of the capital cost of CSP plants can be attributed to the following:

- Relatively longer project preparation cycle time and higher costs in obtaining permits and clearances
- Higher cost of labor
- Relatively more stringent environmental regulations and requirements

Though the cost of a CSP plant in India is lower than the cost of a CSP plant in United States and Spain, it is still higher than several renewable energy based electricity supply options (Table 3) such as wind power and solar PV power in India (WEC, 2013).

Results of a preliminary attempt to review the potential avenues for cost reduction and to assess the effect of any such cost reduction on LCOE are presented in the following sections.

Drivers of cost reduction of CSP plants in India

A CSP power plant consists of several important hardware components that critically affect the performance and cost of the plant. For ensuring market competitiveness of a CSP plant, each one of the components must satisfy certain basic requirements. Table 4 summarizes some of these requirements. Cost of CSP technology is expected to reduce through technological breakthroughs/innovations and local manufacturing of components used in CSP plants (ESMAP, 2012; IRENA, 2012; IEA, 2014).

Significant cost reductions are expected to be achieved through the use of alternative mirror materials, using mirrors of high reflectivity,

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