

Bankability of Concentrated Solar Power in India: A Plant-Configuration Case Study in Hyderabad, Bangalore, and Mumbai

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Overview

India's Jawaharlal Nehru National Solar Mission (JNNSM), launched in January 2010, is intended to help address energy poverty and the resulting economic and social consequences. Under the new Modi administration, the JNNSM solar deployment goal was increased to 100 GW (WEForum 2014).¹ While Phase 1 has been successful in deploying solar photovoltaic technology in a cost-effective manner, it has failed to deploy solar thermal technology such as concentrated solar power, CSP (Shrimali and Nekkalapudi 2014). One barrier preventing further CSP deployment is cost, specifically high up-front capital costs. Indeed other benefits beyond costs, such as dispatchability, may need to be explicitly considered to justify CSP investments when a relatively high renewable penetration is targeted in the electricity mix (Brand, Boudghene Stambouli et al. 2012).

While not as successful to date as solar photovoltaics (PV) power, CSP deployment has recently been on the rise, with 3.4 GW of installed capacity globally (REN21 2014). The Indian CSP industry showed great enthusiasm during Phase I of JNNSM with 66 bids for a total capacity of 2,911 MW (of the required 470 MW). However, as noted, this enthusiasm has yet to translate into installed capacity: as of June 2014, only 50 MW CSP capacity was completed, due to logistical issues such as construction delays and lack of sufficient water supply for cooling (Shrimali and Nekkalapudi 2014). With sufficient hybridization or thermal energy storage, or a combination of the two, CSP can become a dispatchable electricity source, enabling continued or selective operation at times of high demand, and may even lower the delivered cost of electricity.

This study evaluates options for deployment configurations of current CSP technologies that may decrease the LCOE or exploit other attributes of the technology that could make it a more attractive investment in India (e.g., shift the time of availability). Specifically the research addresses the following questions:

1. How do different combinations of hybridization and thermal storage (referred to herein as system configurations) impact the LCOE of CSP power plants? How do these configurations impact IRR and total electricity delivered to the grid?
2. Does the bankability of different configurations for CSP depend on geographic location and the attendant solar resource? How do cost and system configuration trade off with other attributes, such as dispatchability and time-of-day of availability?
3. What policy insights can we gain from such a configuration analysis?

Methods

This study utilizes a publicly-available techno-economic tool, the CSTEP Model (CSTEM), to analyse the cost of large-scale CSP in India, in particular parabolic trough (PT) CSP. The model evaluates the levelized cost of electricity (LCOE) produced by the plant for different solar multiples (SM), using specified levels of thermal storage or hybridization and cost parameters for different locations (Ramaswamy, Chandrasekaran et al. 2012). This analysis assumes a hypothetical CSP power plant with 50 MW installed capacity. The reference case has neither thermal storage nor hybridization. We also consider cases where 6 hours of thermal storage or 20% hybridization (with natural gas), or both, is provided to the reference power plants.

¹ The original 2010 goal of 20 GW would have entailed the installation of approximately 20 million square meters of solar collectors and distribution of 20 million solar lighting systems in rural areas; the expanded goal will therefore increase this by approximately a factor of 5.

In this analysis, we examine several different potential configurations of CSP, with a focus on utilization of current technologies and under the contemporary policy and financial landscapes. This set of constraints represents the deployment choices that can be modified according to the attributes of delivered electricity from CSP projects, in the near-term, and with very little or no assumed technological progress and no significant policy changes. Since the competitiveness of CSP technology compared to conventional energy sources is largely determined by the unit cost of generation, here we define “optimal choice” primarily as the configuration that yields the lowest LCOE. As noted, the LCOE is measured as the ratio of the present value of project expenses (i.e., total capital and O&M costs) to the present value of electricity delivered to the grid. Two other key metrics we consider are total electricity delivered to the grid and the internal rate of return (IRR) to investors.

Results

The study confirms the intuitive result that optimal solar multiple value decreases as solar resources increase. The associated LCOE is always reduced when going from low-solar resource locations (i.e., Mumbai) to those with higher resources (i.e., Hyderabad). The greatest “value” associated with the addition of hybridization or storage is afforded to different locations depending on the scenario and the metric of interest (e.g., delivered electricity);

Adding both thermal storage and hybridization will lead to the largest amount of electricity sent to the grid. However, due to the extra cost of these systems, the capital costs will also increase significantly. These two factors will trade off in different ways depending on the geographic location. For example, by adding both thermal storage and hybridization, a 50 MW CSP plant at Mumbai would increase electricity sent to the grid by 87% while its LCOE decreases by 10%. On the other hand, the LCOE decrease at Hyderabad would be slightly less dramatic, 7%, but with a higher relative level of increased electricity delivered to the grid (98%) after adding in the thermal storage and hybridization. This is due to the fact that in places where the solar resource is most abundant, adding the thermal storage will extend the hours of power availability but at a larger cost due to the larger increase in the optimal SM choice. In places where solar resources are relatively scarce, adding thermal storage and increasing the size of solar multiple can increase the power generation but may not extend the hours of power availability significantly. However, when considering the design of CSP power plants at places where solar resources are scarce, thermal storage and hybridization may still be relatively more beneficial additions despite their extra costs (e.g., if IRR is the metric of interest).

Conclusions

- Changes in the configuration of concentrated solar power (CSP) systems, including the choice of solar multiple (SM) and whether or not to deploy hybridization or thermal storage, change the bankability of solar (i.e., IRR and LCOE) and the amount of electricity sent to the grid.
- The inclusion of hybridization and storage has different “value” depending on geographic location and corresponding solar resources, and configurational choices may change cost and delivered electricity in non-intuitive ways.
- When working to meet aggressive solar goals, the Indian government should consider different configurations of plant designs, such as inclusion of hybridization and thermal storage units, as well as the geographic emphasis of overall solar-deployment goals to shape and improve the outcome of large-scale solar deployment.

This research is based upon work supported by the Solar Energy Research Institute for India and the U.S. (SERIUS).

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