



Techno-economic parametric assessment of solar power in India: A survey



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ABSTRACT

There are two ways by which solar energy can be harnessed viz. solar Photo-Voltaic (PV) and Concentrating Solar Power (CSP). This paper focuses on the parameters required for the commissioning of solar power plants in India using these technologies. The key parameters have been identified through the literature review and discussion with the experts. The parameters thus obtained, are classified under PV and CSP technologies and then categorized into technical and economical parameters. A survey is conducted to understand the perceptions of Indian key players in the area of solar energy and to rank forty one identified parameters. Analysis of survey shows that location of the site and direct investment cost are the highest preferred technical and economical parameters respectively. The results of this study will help decision makers and policy makers of solar technologies in India.

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1. Introduction

India lies in the sunniest regions of the world with 250–300 clear sunny days. Solar energy, if harnessed can play a major role in reducing India's power deficit. Various technologies are used to convert solar irradiation into usable form of energy like thermal and electricity [1]. Solar thermal energy can be utilized for process heating applications, solar water heating systems, drying of biomass etc. Electricity is generated through solar, mainly in two ways, one being direct conversion of solar radiation into electricity

(using PV) and other by indirect conversion in which concentrated solar energy heats up fluid stream which runs the conventional thermal power plant cycles [2]. PV which is direct electricity generation technology is proven and tested commercially. Multi-megawatt generation plants based on PV technology have already been in operation all over the world for decades. The Concentrating Photo-Voltaic (CPV) is comparatively an emerging technology as compare to PV [3]. In India, the power generation through PV has gained pace after the year 2002 [4]. CSP systems which uses indirect conversion technology are categorized by the way solar energy is focused and received. These systems are classified as (a) parabolic trough collectors (b) linear Fresnel collectors (c) central receiver systems (d) parabolic dishes and (e) Scheffler systems [5]. This classification is based on their focus geometry as

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either line-focus concentrators (parabolic-trough collectors and linear Fresnel collectors) or as point-focus concentrators (central receiver systems, parabolic dishes and Scheffler systems).

The Jawaharlal Nehru National Solar Mission (JNNSM), one of the eight National Missions under National Action Plan on Climate Change, which was launched on 11th January 2009 with funding of USD 930 million. It is an ambitious mission to make India a global leader in solar energy by generating 20,000 MW of solar power by 2022 [6]. The JNNSM is sub divided into three phases. Phase I targeted for 1000 MW by end of March 2013 and crossed the set target with installed/ allotted capacity of 1236.48 MW with stipulated period of time. Phase II has the target of 5000 MW till 2017. As of January 2014, the cumulative grid connected installed capacity of 2208.36 MW and off grid 159.77 MW of solar power has been achieved [7]. Majority of the solar installed capacity is of PV as compared to that of CSP.

As compared to PV, CSP technologies started with slow pace since its inception in nineties due to various factors favoring PV like decreasing cost of PV, ease of commissioning and less maintenance of PV systems, and to some extent poor political and financial support for CSP by Government of India. For instance, it was planned to set up a 35 MW power plant based on CSP in Mathania, Rajasthan in year 1994, but the project has not seen the light of the day due to lack of encouragement from government resulting in short of sufficient bidders and contractors. But, with the onset of JNNSM the scenario is now changing, resulting in rapid development in the area of CSP [8]. From 2010 to 2012, many CSP projects were introduced in India. The government of Rajasthan reinitiated the Mathania solar power project with an additional capacity of 105 MW from conventional sources, giving combined capacity of 140 MW integrated solar combined cycle power plant [9]. The current installed capacity of CSP in India, as of July 2013, is 55.5 MW which is just 2.51% of PV installed capacity [10]. This disparity between PV and CSP is due to the various factors like maintenance, grid connectivity, ease of commissioning, government policies; availability of water, which is the key factor for CSP plants for both cleaning of mirrors and running turbines specially in arid regions like western Rajasthan and Kutch of Gujarat. Despite these problems, CSP is gaining momentum in these areas as this part of the country is blessed with high solar insolation and CSP has advantages like it can be hybridized with conventional fossil fuel system and can generate power continuously with thermal storage. The CSP plants with collective capacity of 585 MW are under construction in Rajasthan, out of which only 52.5 MW has been operational till date. An operational plant of 1 MW, in Gwal Pahari Haryana, is solely for research and development purpose of Ministry of New and Renewable Energy (MNRE). In Andhra Pradesh around 100 MW and in Gujarat 45 MW of CSP plants are under construction. Similar to CSP, many projects on PV are also under constructions in Gujarat, Rajasthan and Tamil Nadu. It is expected that PV and CSP will further gain momentum in near future, thus makes the need to review technical and economical parameters for PV and CSP especially in Indian context. This paper tried to find out the key parameters required for the deployment of solar technologies in Indian context.

2. Review of techno-economic assessment

Techno-economic assessment for various solar power generation technologies, viz, PV and CSP, has been attempted by various researchers. For instance, In PV technologies, Fthenakis [11] gave a technical, geographical, and economical feasibility for solar energy to supply the energy needs of the USA. A solar power plant pre-feasibility study by Cameron [12] shows that the size of the plant

is a key determining factor, followed by location and cost. However the details presented are with reference to Australian scenario. The Handbook for PV systems [13,14] shows that temperature also plays an important role on the life span of solar cells. The report describes the use of solar equipments like modules, inverters, batteries etc. A study by Branker et al. [15] found out that solar thermal electricity is an economically viable technology under favorable conditions, i.e. in areas with high insolation levels. At a global level, the International Energy Agency (IEA) has prepared technology roadmaps for PV as well as for CSP [16–18], which projects that solar electricity could represent up to 20% to 25% of global electricity production by 2050 and that CSP could supply over 10% of the world's electricity by the same year. In India, a roadmap is prepared by the MNRE [19], under the authority of Government of India. Soni and Mellacheruvu [4] discussed in detail about Concentrating Solar Photovoltaic (CPV) and possible impact of the same as compared to PV in Indian market.

“A research on CSP with levelized cost” by Nezamhahalleh [20] presented the technical and economical assessment of the integrated solar combined cycle power plants in Iran. In the research article, thermal efficiency, capacity factor, environmental considerations, investment, fuel and O&M costs are the main parameters considered for technical and economical assessment of solar power plants. Eck et al. [21] suggest that direct steam generation is a promising option to improve the solar thermal electricity generation efficiency. According to Mills [22] solar thermal electricity generation systems are emerging among the renewable energy technologies available. A research by National Renewable Energy Laboratories (NREL) shows that, in USA large scale deployment of CSP plants with careful land and water usage would have ecological impacts which can be managed through sensible deployment of solar resources [23]. One of the key works in the field of CSP is done by Vogel and Kalb [24], which discusses the technical and cost factor for commissioning of solar thermal based power plants. Morin [25] considered the technical parameters like heliostat fields, operating temperatures, thermal storages etc for his study. Assessment report on parabolic trough and solar tower by Sargent and Lundy [26] shows that in a long run CSP will prove to be the main source of power generation technology. From the above literature survey, it was found that most of the research work has been done in the area related to the development of PV and CSP technologies. In case of technical assessment the concept of grid parity and levelized cost of electricity is used [27]. The technical details like location and weather is also discussed in some of the research papers, however they are restricted to particular technologies and location. Economic assessment comparisons of various technologies are done on the basis of direct cost and operational cost.

Literature also showed some research work related to expert survey in the field of renewable energy. For instance, Heo et al. [28] surveyed using five decision making criteria and seventeen factors for the assessment of renewable energy dissemination program in Korea. Similarly, Komendantova et al. [29] took a brief survey from the stakeholders on the potential barriers in renewable energy and discussed the political risks connected with technology. A report by International Renewable Energy Agency [30] showed the perception of solar parameters for the use of ‘Global Renewable Energy Atlas’ from the responses of ‘Solar and Wind Resource Assessment’ tool users. Another survey report for IEA by Group on Earth Observation [31] on Solar Heating and Cooling Program shows the essential parameters of solar energy for the improvement of solar resource assessment software. Research work by Bosetti et al. [32] discussed the elicitation survey from 16 experts from Europe. The survey was on future prospects of PV and CSP technologies with Research, Development

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