Renewable and Sustainable Energy Reviews 45 (2015) 698–709

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Challenges and opportunities for Solar Tower technology in India

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A R T I C L E I N F O

Article history:
Received 20 May 2014
Received in revised form
8 December 2014
Accepted 7 February 2015
Available online 27 February 2015

Keywords:
Solar Tower
Global review
Operational
Under construction
India
JNNSM

A B S T R A C T

Solar Tower technology has gained considerable momentum over the past decade. Unlike the parabolic trough, Solar Tower has a lot of variants in terms of type of receivers, working fluids, power cycles, size of heliostats, etc. Most of the literature available on this technology does not address in great depths, details of various parameters associated with tower technology. A detailed examination of plant parameters is required in order to perform a potential assessment, design basis or feasibility analysis. This paper aims to assess the principal parameters of existing plants, namely, solar to electric conversion efficiency, mirror and land area per MW_e of equivalent capacity, packing density, field layout configuration, receiver size, tower height and gross costs of plants, wherever data is available. Based on this global review of existing plants, it is observed that, the annual solar to electric conversion efficiencies has an average value of 16% and the packing density has an average value of about 20%. Since most of the existing plants have been constructed for demonstration purposes, the true potential of this technology has not yet been realised. Using this assessment as a basis, the technical, financial and policy drivers and barriers for adopting tower technology in India are discussed. It is seen that based on indigenisation prospects, tower technology with external cylindrical or cavity receivers with storage could be adopted. The role and significance of this technology is brought out in the context of the Jawaharlal Nehru National Solar Mission (JNNSM) in order to achieve grid-connected solar power. It is estimated that around 1800 MW of grid connected Solar Tower plants could come up under this mission by 2022.

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http://dx.doi.org/10.1016/j.rser.2015.02.016
1364-0321/

1. Introduction

Solar Tower (ST) technology, which is also referred to as Central Receiver Technology, uses a large number of heliostats having a dual axis control system (one about the elevation axis and the other about the azimuthal axis). These heliostats reflect direct beam solar radiation (impinging on their surface) to a stationary receiver located at the top of a tower. In the receiver, Heat Transfer Fluid (HTF) gains heat and transfers this thermal energy to the power block to generate electric power. This technology has evolved over the past 20 years. Even though it dates back to the late 1980s, over the past decade, a considerable increase in the number of operational ST plants has been observed. The capacity of plants under construction indicates that the growth of ST technology is on par with that of Parabolic Trough (PT) technology [1] (see Table 1).

This paper presents an analysis of the challenges, opportunities and potential of ST technology for Indian conditions, based on a gross assessment of certain parameters of existing plants worldwide. Based on available information, solar to electric conversion ratio, mirror and land area variations with equivalent capacity, field layout configurations, working fluids employed, receiver size estimation, tower height, and gross costs of plants have been examined. Furthermore, an assessment of available solar and land resources in India, technological expertise in terms of engineering, design and manufacturing have also been discussed. Based on this assessment, the potential of ST technology for Indian conditions is estimated.

Most of the literature available on the existing ST plants discuss the overview, plant construction and characteristics [2–5]. Studies have also been conducted on operation evaluation, modelling and simulation of specific components of plants [6,7]. A design of reference plants using particular heliostats has been proposed [8]. Also, specific reviews of ST plants [9] as well as reviews of all the Concentrated Solar Power (CSP) technologies (which includes ST) have been performed [10,11].

While most of the literature identified, discuss in depth, the performance characterisation of components of particular plants, they do not present a methodological assessment of ST parameters. In this paper, a detailed assessment of various parameters of existing ST plants is presented. This is used to infer the challenges and opportunities for employing ST technology in the Indian context.

The total installed capacity of ST plants worldwide is shown in Table 1. It has been compared with PT technology to identify the growth potential of ST in the next few years.

In India, the experience with ST is very limited and is yet to gain momentum. The Jawaharlal Nehru National Solar Mission (JNNSM), one of the eight missions under the Prime Minister's National Action Plan for Climate Change (NAPCC), was released in 2010. The objective of this mission is to achieve 20 GW of grid-connected solar power and 2 GW of off-grid solar power by 2022. The targets set by JNNSM on capacity addition, are shown in Table 2. Planning supported by technology improvement and policy support can lead to high level of solar additions in India.

Section 2 of this paper discusses the assessment of existing plants based on various parameters like solar to electric conversion efficiencies, mirror and land area used for various ST technologies, field layout, tower height etc. Section 3 discusses the challenges and opportunities for ST in India based on technical, financial and policy perspectives for critical parameters. This is done in terms of resource availability (solar and land) and technological expertise (engineering, design and manufacture).

2. Assessment of existing plants

Tables 3 and 4 provide information on certain parameters of existing plants, both in operation and under construction. Based on the information available, assessment of the ST plants was carried out, and is discussed in this section.

2.1. Overall efficiency of conversion of solar to electric energy

The solar to electric conversion efficiency of any plant is defined using Eq. (1).

$$\eta_{s-e} = \frac{\textit{Annual electricity generation}\ (\mathrm{MWh})}{\textit{Annual solar resource}\ (\mathrm{MWh}/m^2) \times \textit{Heliostat field area}(\mathrm{m}^2)} \quad (1)$$

Table 1
Global status of ST and PT CSP plants [1].

Technology	Solar Tower	Parabolic Trough
Operating plants capacity (MW)	457	1168
Under construction capacity (MW)	1197	1377

Table 2
JNNSM capacity addition targets [12].

JNNSM policy targets (cumulative)/year	Phase 1 (2010–13)	Phase 2 (2013–17)	Phase 3 (2017–22)
Utility grid power (MW)	1100	10,000	20,000
Off-grid solar application (MW)	200	1000	2000