Solar Energy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Solar Energy

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

# Reprint of: Dealing with dust – Some challenges and solutions for enabling solar energy in desert regions☆

Nibodh Boddupalli[a], Gurveer Singh[a], Laltu Chandra[a,*], Bibek Bandyopadhyay[b]

[a] Indian Institute of Technology Jodhpur, Rajasthan 342011, India
[b] Indian Institute of Engineering Science and Technology Shibpur, West Bengal 711103, India

ARTICLE INFO

*Keywords:*
Dust deposition
PV/heliostat
Large eddy simulation
Open volumetric air receiver

ABSTRACT

In India, the desert regions of Rajasthan and Gujarat are preferred for installation of solar photovoltaic (PV) and concentrated solar thermal (CST) systems because of a high level of both DNI and GHI components of solar radiation. However, such regions pose substantial challenges in terms of dust, a high ambient temperature and scarcity of water. This paper is an attempt to address issues related to the deposition of dust (a) on a mirror with stand depicting PV panel or heliostat in the wake of a similar geometry and (b) in the porous absorber of an open volumetric air receiver (OVAR). A detailed insight to the wake-region behind an inclined flat-plate or heliostat is provided based on analysis and experiment. These indicate possible measures such as modification of the geometry of collectors to mitigate the problem of dust deposition. Also, the use of a cyclone separator with defined parameters based on a decision variable has been suggested for reliable operation of an OVAR. These problems being generic in nature, similar strategies are expected to be applicable in other desert regions subject to their specific conditions.

## 1. Background

The Thar desert, also called the Great Indian Desert, is a large arid region with little rainfall distributed erratically. The landscape is dominated by sand dunes. The desert has its maximum area in the state of Rajasthan and extends to the Rann of Kutch in the state of Gujarat in India (Fig. 1). Some parts of the states of Punjab and Haryana also experience the desert like situation. Since the soil of the desert remains dry in most part of the year, it is subjected to wind erosion. As a result, the sand of the desert is highly detachable and mobile. Like many deserts in the world, the desert in Rajasthan and Gujarat receives abundant solar radiation (Fig. 2) with daily incidence averaging more than 6.5 kWh per sq. meter of GHI (Global Horizontal Incidence).

Since the area has low rainfall, about 325 days have good sunshine in a year, and in the western areas in Thar desert, it may extend up to 345–355 days as rains occur only for 10.4–20.5 days in a year. The annual DNI (Direct Normal Insolation) over the desert regions of Rajasthan and Gujarat varies from 1800 to 2200 kWh per sq. meter. This makes these regions comparatively suitable for Concentrating Solar Thermal (CST) power plants.

The National Solar Mission of India targets 100 GW of solar power installation by 2022. With a good solar insolation, comparatively easy availability of land, and favorable policy initiatives, the states of Rajasthan and Gujarat will thus be the destination for solar power projects. India has, till September 2016, a total installed solar power capacity of 8.6 GW. Out of this Rajasthan alone has an installed capacity of 1.29 GW whereas Gujarat has installed more than 1.13 GW of solar power plants. Most of these power plants are based on solar photovoltaic (PV) technology. However, in Rajasthan a 50 MW of CST plant is already in operation and a few more CST plants are expected to be commissioned soon. The performance data of the so far installed power plants in the desert regions of Rajasthan and Gujarat suggest that dust is a detrimental factor. Jodhpur in the state of Rajasthan is called the sun-city of India. The district of Jodhpur has around 300 MW of commercial solar power plants currently under operation. The Indian Institute of Technology Jodhpur (IITJ) aims to address this issue. As an example, two problems pertaining to dust deposition and probable solutions or strategies to mitigate these issues are presented in the subsequent sections. It must be noted that, even though the considered problems are based on experience at Jodhpur, these are equally

DOI of original article: http://dx.doi.org/10.1016/j.solener.2017.04.032
☆ The article is reprinted here for the readers' convenience and for the continuity of the special issue. It was previously published in regular issue, Volume 150, due to a production error. For citation purposes, please use the original publication details [Sol. Energy 150 (2017) 166–176, http://dx.doi.org/10.1016/j.solener.2017.04.032]. We apologize to the authors and readers for any inconvenience caused.
* Corresponding author.
*E-mail address:* chandra@iitj.ac.in (L. Chandra).

http://dx.doi.org/10.1016/j.solener.2017.04.073
Received 5 November 2016; Received in revised form 30 January 2017; Accepted 11 April 2017
0038-092X/ 

**Fig. 1.** The Thar desert in India in red. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

important for any desert region worldwide.

## 2. Dust-deposition and air-flow around a PV panel/heliostat

### 2.1. Introduction

Rajasthan is a dry arid region with the basic wind speed of about 47 km/h (IS 875 Part 3) [see e.g. Lakshmanan et al. (2009)]. This is based on the peak gust speed averaged over the 3 s at a height of 10 m in an open terrain. Jodhpur has sandy-loam type of soil, see Table 1. This clearly reveals a high concentration of fine sand, which is more likely to be deposited on solar photovoltaic (PV) panels and in concentrated solar thermal (CST) system with, for instance, heliostat as a reflecting surface. Such depositions are already reported on the

**Table 1**
Soil composition in Jodhpur [Gupta (1986)].

| Soil Type | Size (μm) | Percentage (%) |
|---|---|---|
| Coarse sand | 250–1000 | 10.5 |
| Fine sand | 50–250 | 74.8 |
| Silt | 2–50 | 4.8 |
| Clay | < 2 | 9.9 |

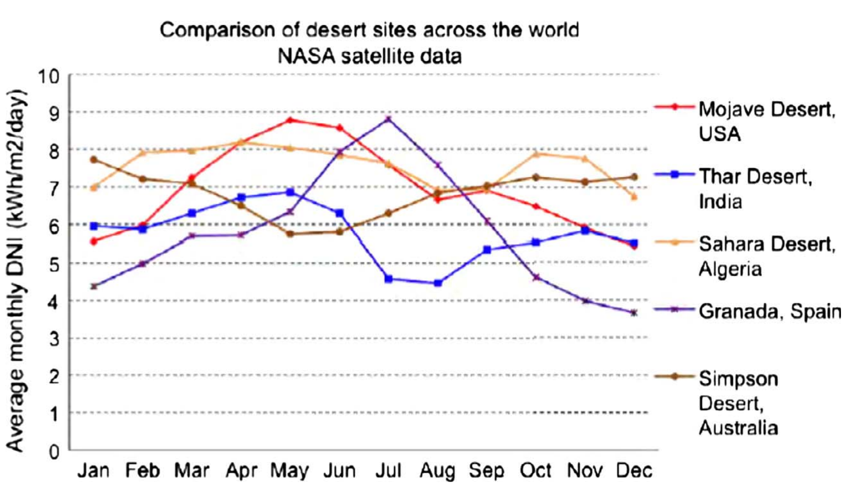


**Fig. 2.** Comparison of DNI on a monthly basis for desert sites across the world.
*Source:* http://eosweb.larc.nasa.gov/.