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Concentrated solar power technology in India: A review

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ABSTRACT

Conventional power plants suffer from issues like fuel scarcity, availability of site and other environmental concerns. Alternate technologies based on renewable energy sources especially solar, wind and bio-mass are utilised to overcome these problems. Among many options available in solar technology, power generation through CSP (Concentrating Solar Power) could be the most promising one for India in the coming future. In this paper, a brief overview on various CSP technologies and site selection criteria has been outlined. Subsequently, the design considerations for the four major CSP technologies i.e. solar tower, parabolic trough, linear fresnel reflector, and parabolic dish are discussed. Finally, the present status and key issues related to the deployment of CSP based technologies in India are summarised.

Contents

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Nomenclature

Abbreviations

CSP	Concentrated Solar Power
GHI	Global Horizontal Radiance
GNI	Global Normal Radiation
DNI	direct normal radiation
PCM	phase change material
LFR	linear fresnel reflector
PT	parabolic trough
PD	parabolic dish
CRT	central receiver tower
CR	concentration ratio
HTF	heat transfer fluid
UTS	ultimate tensile strength
MNRE	Ministry of New and Renewable Energy
ONGC	Oil and Natural Gas Cooperation, India

Symbols

A	Area
E	energy
I	irradiance
T	Temperature (K)
d	Diameter of tube (m)
E	Modulus of Elasticity (Pa)
k_t	Conduction Through Tube
$q_{t,j^{th}}$	Heat
$\dot{m}$	Mass flow rate
c_p	Specific Heat
c	collector
b	Boiler
o	outer
i	inner
j	queue number
f	final

Greek Letter

σ_{max}	Maximum Thermal Stress (Pa/sq.m)
α	Coefficient of Thermal Expansion ($^{\circ}C^{-1}$)
ζ	Poisson Coefficient (dimensionless)
η	Efficiency

1. Introduction

Sun is the only source of energy for earth and every living organism right from plants to animals thrive on this source. Annually earth receives around 885 million TW h of solar energy, which is around 6200 times the commercial energy demand of the entire population of the world [1]. The solar energy reaches the earth in the form of radiations and on a clear sky day the solar energy falling on the earth surface is around 1000 W/m^2 near zenith. The solar radiations are of three major types—direct or beam radiation, diffuse radiation and reflected radiation. Direct radiation is the solar radiation which travels on a straight line from the sun down to the earth's surface while the radiations scattered by the particles in the atmosphere are termed as diffused radiation. Reflected radiations are the one which are reflected by any object other than the atmosphere e.g. from ground, buildings etc. The sum of direct, diffused and reflected radiation is called the global solar radiation [2]. Solar energy is received on earth, in the form of short wave radiation travelled through space and air [3]. After travelling through space and air, the maximum part of radiations comes straight to the surface called beam radiation; however some portion gets diffused in air named as diffuse radiation. Global horizontal irradiance (GHI) is the total amount of short wave radiation received from the sun by a horizontal plane on earth. GHI includes both direct normal irradiance (DNI) and diffuse horizontal irradiance (DHI). The beam radiation falling at right angle to the plane of incidence is the only useful part to concentrate known as direct normal irradiance (DNI) and the plane is known as reflector plane. DNI is the intensity of solar energy received on a plane normal to the sun radiation.

CSP technologies utilise DNI for power generation and require a cut in value of 200 W/m^2 to generate electricity below which the thermal losses in the system hinder power generation [4]. Though a DNI greater than the cut in value may successfully produce power, yet power generation by CSP plants become economical only at values greater than 1800 kW h/m^2/year [5]. Weather conditions, aerosol content and air mass affects the DNI and a high value of DNI is received only on a clear sky day in hot and arid environment. Therefore, the regions near the equator or between the tropic of Cancer and tropic of Capricorn like north western parts of India are best suited for power generation through CSP.

Utilisation of solar energy started with industrial water heating. From 1980 onwards standalone CSP power generation units started to supply electricity to the grid [6]. The present CSP technologies are capital intensive and having high levelised cost of electricity (LCOE) as compared to other available renewable based technologies like solar photovoltaics (PV), Wind energy and biofuels [7,8] still it has many advantages over them. Firstly electricity supplied through CSP plant is more reliable because of its storage capability[9,10]. Secondly, CSP technologies could be integrated in present infrastructure like coal/gas [11] based thermal power plants as both have similar operational characteristics [12]. Lastly, it has been found out that CSP power plants can be set up easily, as their constituent components are made up of common industrial materials like steel, glass etc. With time, as the manufacturing techniques improve, the capital and operation costs are expected to comes down [13,14]. Moreover, a wide range of options are available right from low capacity systems for residential use, the medium capacity for hybrid facilities to the large scale standalone CSP power plants [15–17]. The paper begins with the concept and components of CSP and then moves onto site selection factors and various commercially available technologies. Subsequently, the status of CSP technology and the key issues related to the deployment of CSP based power plants in India are highlighted.