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Solar energy potential and performance assessment of CSP plants in different areas of Iran

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Abstract

Concentrating solar power (CSP) plants only exploit direct beam solar radiation in order to generate electricity. It is generally assumed that CSP systems are economic only for locations with direct normal irradiation (DNI) above 1800 kWh/m^2/year (about 5 kWh/m^2/day). In the present study, talented regions of Iran to install CSP plants are identified by using the available measured data of global horizontal irradiation (GHI) from 21 cities. A computational code converts the measured GHI to DNI and by comparing the calculated data, six most talented city area of Iran are selected as the case study. By applying geographical, radiation and meteorological parameters to SAM software, the generation of electricity for a typical CSP plant for these locations are evaluated. The selected CSP plant is a parabolic trough (PT) power plant with capacity of 100 MW and 6 hour thermal storage. Results show that areas around the cities of Bandar-e Abbas, Bushehr, Esfahan, Kerman, Shiraz, and Yazd have more solar energy potential to establish CSP plants in Iran. Annual electricity power for these cities are calculated to be about 234 GWh, 245 GWh, 283 GWh, 318 GWh, 321 GWh and 318 GWh, respectively. Furthermore, employment of solar energy in these areas for electricity generation, considerably conserve fossil fuels and reduces CO_2 emission. Also, a comparison of DNI and power plant electricity generation in the 6 talented cities of Iran and 4 cities of Algeria are performed.

Keywords: Assessment; CSP; Direct normal irradiation; Iran; Parabolic trough; SAM; Solar potential

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1. Introduction

Energy demand has a significant growth in the recent century due to population growth, development programs and attempt of growth in developing countries as well as new industrial growth in the globe. Fossil fuels have the main role to supply this energy requirement among different types of energy sources. Unavailability of fossil fuel in all regions, high cost, their depletion and air pollution are the most disadvantages of fossil fuels consumption. As a solution to these concerns, development and implementation of new energy resources like nuclear and renewable energies are undeniable. Solar energy as one of the most accessible and reliable renewable energies has experienced an extensive development in the last two decades. Lower cost and higher production efficiency of CSP leads to extend CSP in commercial scale in several countries. CSP technologies exist in four forms; Parabolic Trough, Dish Stirling, Concentrating Linear Fresnel Reflector and Solar Power Tower, among which, solar power tower and parabolic trough are the two main approaches of a large-scale application of CSP systems.

Establishment of a CSP plant requires pre-feasibility study which is included solar energy resource, cost and water supply analysis. The first step in pre-feasibility of CSP plants is solar energy potential assessment. Total solar horizontal energy, GHI, consists of two terms; Beam Horizontal Irradiation (BHI) and Diffuse Horizontal Irradiation (DHI). The CSP technologies only exploit DNI (BHI⁄cos(z), where z is zenith angle) to produce electricity and CSP plants have economic justifiability only for locations with DNI above 1800 kWh/m^2/year [1]. The NREL's SAM software (System Advisor Model) is able to evaluate the plant's energetic and economic performances. SAM software receives the geographical, meteorological and radiation data like latitude, temperature and DNI and by simulating the CSP system, presents desirable outputs such as annual energy output, capacity factor and efficiency.

Several researches have studied CSP plants for different consideration in some countries. Abbas et al. [2] had an assessment of a 100 MW plant for electricity generation based on parabolic trough technology in four typical sites of Algerian climate conditions by using SAM software. Donaji et al. [3] used SAM to assess an annual production between the parabolic trough systems and power tower in Mexico and Spain. Malagueta et al. [4] simulated four types of 100 MW CSP plants with parabolic troughs (simple plants, plants with hybridization and plants with thermal energy storage) based on the SAM at two sites: Bom Jesus da Lapa and Campo Grande. Purohit [5] had a techno-commercial feasibility of four types of CSP plants for 23 locations in India. Izquierdo et al. [6] studied the effect of the solar multiple, the capacity factor and the storage capacity on the cost of electricity from CSP plants. Le Fol et al. [7] first determined suitable areas for CSP and estimated the CSP ceiling generation and subsequently, offered a map of the Levelized Cost of Electricity (LCOE) for a 50 MW CSP plant.

In the present study, DNI for 21 cities of Iran is calculated by available measured data of GHI. By comparing the calculated data, 6 city areas of Bandar-e Abbas, Bushehr, Esfahan, Kerman, Shiraz and Yazd which are more convenient to establish CSP plant are selected as the case study. By using SAM software and applying the calculated value of DNI and the selected meteorological data, output of electricity power for a typical CSP plant with capacity of 100 MW and 6 hour thermal storage for these locations is calculated. Based on electricity generation, values of CO_2 emission reduction and preservation of natural gas are also estimated. Furthermore, a comparison of DNI and power plant electricity generation in the 6 talented cities of Iran and 4 cities of Algeria are performed.

Nomenclature

G_{SC}	solar constant (W/m^2)	K_T	clearness index
H	daily irradiation (J/m^2)	$\bar{K}_T$	monthly average clearness index
H_0	daily extraterrestrial irradiation (J/m^2)	n	day of the year
H_d	daily diffuse irradiation (J/m^2)	nd_k	day of the month
$\bar{H}$	monthly average irradiation (J/m^2)	ndm	number of days of the month
$\bar{H}_0$	monthly average extraterrestrial irradiation (J/m^2)	z	zenith angle (radians)
I	hourly radiation (J/m^2)	δ	declination angle (radians)
I_b	hourly beam irradiation (J/m^2)	ϕ	latitude (radians)
I_d	hourly defuse irradiation (J/m^2)	ω	hour angle (radians)
I_{dn}	hourly direct normal irradiation (J/m^2)	ω_s	sunset hour angle (radians)