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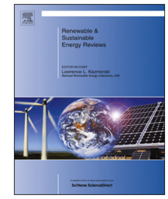

Diffuse solar radiation on a horizontal surface: Reviewing and categorizing the empirical models

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Accessibility to the accurate knowledge of diffuse solar radiation is a fundamental prerequisite for designing and monitoring the solar energy technologies. Nevertheless, the measured diffuse solar radiation is not available in most regions across the globe. During the past 60 years in order to estimate horizontal diffuse solar radiation on both daily and monthly mean daily basis, numerous empirical models have been developed or established for many locations around the world. For this purpose different parameters have been utilized and various functional forms employed. This study aims at providing a review on the diffuse solar radiation models developed, established and proposed thus far. To put forward a proper appraisal, the models are primarily categorized on the basis of how to correlate: (1) the diffuse fraction or cloudiness index (i.e. the ratio of diffuse solar radiation to the global solar radiation), and (2) the diffuse coefficient or diffuse transmittance index (i.e. the ratio of diffuse solar radiation to the extraterrestrial global solar radiation) with different inputs. Both categories, which in terms of the utilized inputs as well as the functional forms constitute 56 different models are re-classified into several main sub-categories and then presented in a chronological manner. This review would be profitable for solar energy researchers in terms of identifying the parameters and the functional forms widely utilized up till now as well as recognizing their significance. Accessibility to either solar and/or meteorological data varies from one location to another; thus, the appropriateness of the models to estimate the horizontal diffuse solar radiation depends on the availability of such inputs at a desired location. Additionally, to attain proper accuracy and reliability of estimation in a desired location the inputs should be selected based upon the fact that how much they can provide strong correlation with diffuse solar radiation.

Contents

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1. Introduction

According to status quo, solar energy is being particularly appealing as an appropriate energy source. Solar energy is clean, environmentally friendly and inexhaustible that can be effectively utilized for many applications [1–3]. Harnessing the solar energy may be profitable to deal with the existing barriers in the field of energy production. As a matter of fact, solar energy technologies and solar power plants can be regarded as suitable substitutes for traditional energy systems for the sake of providing and developing sustainability around the world [4–6]. Nevertheless, in spite of considerable efforts to exploit solar energy via various technologies by scientists, governments as well as investors so far, its potential is fundamentally unexploited yet. About the significance of solar energy it is worthwhile to state that in case of converting only 0.1% of the solar energy arrived at the earth surface to electricity with the efficiency of 10%, the output power would be 17,300 GW, which is 7 times higher than the global average momentary electricity consumption in 2012 [7,8].

Owing to geographic dependency as well as variability of solar radiation, high-quality and reliable information on solar radiation data is unquestionably essential prior to conducting any effort to design and install solar energy systems. In fact, having favorable knowledge of solar radiation is the first and primary step in designing, establishing, optimizing and assessing the output energy of solar energy systems [9–15].

Solar radiation passing through the atmosphere is subjected to variation due to two phenomena: (1) atmospheric scattering by air molecules, water and dust and (2) atmospheric absorption by O_3, H_2O and CO_2. Part of the scattered radiation eventually arrives at the earth surface in the form of diffuse radiation. The measure of radiation scattering depends on the number of particles on its path and the size of the particles relative to the radiation wavelength. The path length of the radiation through the atmosphere is described by the air mass. The number of water and dust particles encountered by the radiation is not only dependent on the air mass but also on the quantities of dust and moisture present in the atmosphere, which are both themselves time and location dependent.

For any particular location, alongside the global solar radiation, the knowledge of its diffuse fraction is an essential element for designing and monitoring the active and passive solar energy systems; from which one application is building illumination [16–20]. Besides, as most of the solar energy applications involve inclined solar surfaces, it is necessary to transform the horizontal diffuse solar radiation to that for inclined surfaces; as an example, the performance of flat plate solar surfaces can be appraised if their tilt is adjusted properly.

Generally, the superior way of knowing the amount of solar radiation at any specific location is to set up the high precision measuring equipment. Solar radiation is measured using different instruments such as Pyranometer and Pyrheliometer. The recorded data may be available for various time scales such as hourly, daily and monthly mean daily. However, due to a series of obstacles such as paucity of required instruments as well as fiscal issues the solar radiation data are not easily accessible, particularly for stations in developing countries and isolated regions. In fact, despite worldwide continuous effort to establish further solar radiation measurement stations in recent years, the number of stations recording the solar radiation, especially the diffuse component, is still limited. As a consequence, it is of indispensible significance to determine the amount of diffuse solar radiation alternatively based upon estimating methods.