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# Comparative study of various correlations in estimating hourly diffuse fraction of global solar radiation

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**Abstract**

Proper design and performance predictions of solar energy systems require accurate information on the availability of solar radiation. The diffuse-to-global solar radiation correlation, originally developed by Liu and Jordan, has been extensively used as the technique providing accurate results, although it is latitude dependent. Thus, in the present study, empirical correlations of this type were developed to establish a relationship between the hourly diffuse fraction ($k_d$) and the hourly clearness index ($k_t$) using hourly global and diffuse irradiation measurements on a horizontal surface performed at Athalassa, Cyprus. The proposed correlations were compared against 10 models available in the literature in terms of the widely used statistical indicators, rmse, mbe and *t* test. From this analysis, it can be concluded that the proposed yearly correlation predicts diffuse values accurately, whereas all candidate models examined appear to be location-independent for diffuse irradiation predictions.


*Keywords:* Hourly diffuse fraction; Clearness index; Standard models; Statistical indicators; Athalassa (Cyprus)

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## 1. Introduction

The increasing global energy demands and increasing fossil fuel prices stimulate countries to downsize energy consumption and exploit renewable energy sources. In addition, environmental problems caused by mass consumption of fossil energy (e.g., global warming), are also reason for concern. For example, the European Union aims at achieving a 25 percent reduction in carbon dioxide emissions by the year 2005; there exists also an additional EU renewable energy obligation that purports to be one of the key mechanisms for enabling the Mediterranean partners to reach their renewable energy targets (20% by 2010). In general, solar and wind energy are thought to be good alternative energy sources for overcoming these problems due to their safety and positive contribution to the global environmental state because of their lack of emissions during operation [1].

Reliable solar radiation measurements for estimating the dynamic behavior of solar energy systems' processes and for simulating long-term operations are required. For thermal analysis performance through transient simulation algorithms, a crucial input is the solar energy components incident on the collector surfaces. Usually, an hourly time step is used in these systems and thus hourly solar energy data are needed which in turn are seldom available at the site of interest. Given global solar irradiation measurements on a horizontal surface (the most widely available data for solar energy) direct and diffuse radiant components can be obtained from global solar energy data through various correlations. Thus, as early as the early 1960s, numerous models for evaluating the diffuse component based on the pioneer work of Liu and Jordan [2] appeared in the literature. These models are usually expressed in terms of 1st–4th-degree polynomials relating the diffuse fraction $k_{\rm d}$ (ratio of the diffuse-to-global solar radiation) with the clearness index $k_{\rm t}$ (ratio of the global-to-extraterrestrial solar radiation). Nevertheless, the range of the diffuse fraction, as reported in the literature, suggests the desirability for recalibration accounting for local climatic differences.

This study investigates the applicability of various standard models correlating hourly diffuse fraction $k_{\rm d}$ and $k_{\rm t}$, in the eastern Mediterranean basin. Of direct pertinence are the works of Orgill and Hollands [3], Reindl et al. [4], Boland et al. [5], Hawlader [6], Miguel et al. [7], Karatasou et al. [8], Erbs et al. [9], Chandrasekaran and Kumar [10], Oliveira et al. [11], and Soares et al. [12], who established hourly correlations between $k_{\rm d}$ and $k_{\rm t}$ under diverse climatic conditions. The models can be categorized as: first-order (Eqs. (1)–(3)), second–third-order (Eqs. (6)–(8)), and fourth-order (Eqs. (9)–(12)) correlations that are briefly reviewed below.

Orgill and Hollands [3] used data from one location in Toronto, Canada, derived the following correlation between $k_{\rm d}$ and $k_{\rm t}$:

$$k_{\rm d} = 1.557 - 1.84k_{\rm t} \tag{1}$$

for $0.35 \leqslant k_{\rm t} \leqslant 0.75$; $k_{\rm d} = 1.0 - 0.249\, k_{\rm t}$ for $k_{\rm t} < 0.35$, and $k_{\rm d} = 0.177$ for $k_{\rm t} > 0.75$.

Reindl et al. [4] studied the influence of climatic-geometric variables on the hourly diffuse fraction based on data from five European and US locations; they established the following expressions:

$$k_{\rm d} = 1.45 - 1.67k_{\rm t} \tag{2}$$

for $0.3 < k_{\rm t} < 0.78$; $k_{\rm d} = 1.02 - 0.248k_{\rm t}$ for $k_{\rm t} \leqslant 0.3$, and $k_{\rm d} = 0.147$ for $k_{\rm t} \geqslant 0.78$.