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On the effectiveness of time and date-based sun positioning solar collector in tropical climate: A case study in Northern Peninsular Malaysia

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ABSTRACT

This paper provides detailed information on the developed hardware and software for sun tracking mechanism and shows the effectiveness of utilizing time and date-based sun positioning solar collector system in tropical climate. The sun positioning system is based on the calculated azimuth and altitude at location E100°11′, N6°26′ in Northern Peninsular Malaysia where the climate is categorized as tropical climate. The system has two axes tracking with accuracy of 1° controlled by a programmable logic controller (PLC). The field test has been done during a sunny and clear day, cloudy day and, heavy overcast and rainy day in which the results show that the improvement in the generated power of 91.97%, 122.71% and 90.42%, respectively, as compared with the fixed horizontal system.

Contents

1. Introduction

Renewable energy (RE) is the solution for a sustainable, clean and cheaper energy. Current state and prospects of RE in Malaysia is promising [1–4]. Solar energy particularly is abundant, and the potential in electricity generation from solar energy in Malaysia is suitable and are among the highest worldwide [5–8]. Solar PV systems, in particular, are still in the going for full utilization despite the government efforts in enhancing the current incentives through several policies and programs [9–12]. However, currently, the available PV systems in Malaysia are stand alone PV. Although the Malaysian climate is characterized by heavy rainfall, high temperature and high relative humidity of greater

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Nomenclature

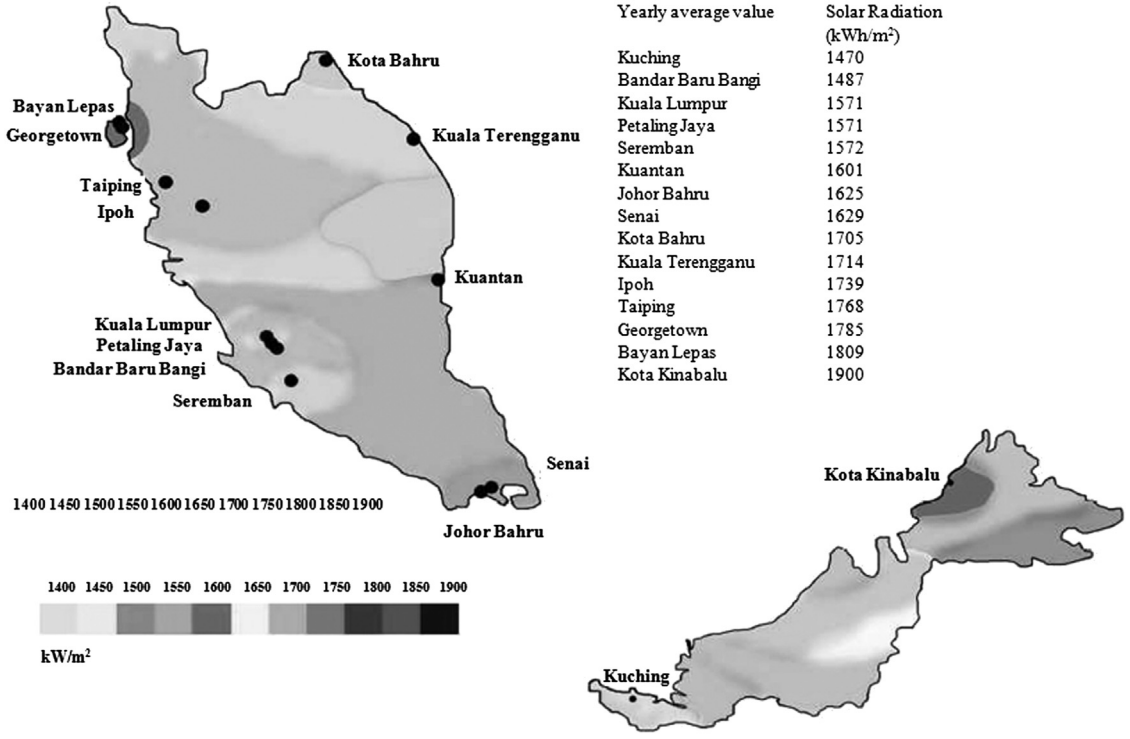
I_D	Direct irradiance
I_{DN}	Direct normal to surface irradiance
θ_i	Incidence angle
I_{ext}	Extraterrestrial irradiance
I_c	Solar constant
N	Number of days in a year
α	Solar altitude angle
φ	Local latitude
δ	Solar declination angle
ω	Local hour angle
γ	Solar azimuthal angle

than 60%, a drawback to solar PV energy collection, the northern state in Malaysia is among the location with the highest potential of high annual average daily global solar radiation. Malaysia, in general, has an average of 6 h sunshine per day and maximum of 8.7 h average per day in January with a high average ambient temperature ranging from 26 °C to 32 °C annually [13]. Based on previous studies, solar powered devices are sufficient for operation with average daily solar radiations between 4.21 kW h m^{-2} to 5.56 kW h m^{-2} [2]. The yearly average global solar irradiation distributions in Malaysia vary with the highest value of 1900 kW h m^{-2} in Kota Kinabalu followed by a district in Northern Malaysia state, Bayan Lepas with 1809 kW h m^{-2} as in Fig. 1. Estimated, with only 0.6% PV panel covering Peninsular Malaysia, electricity demand in 2007 of 86.5 TW h can be fulfilled [14].

Solar tracking is a proven method to significantly improve the energy collected from the sun compared to fixed panel. Different sun tracking systems and approaches has been used to track the dun accordingly. There are various approaches to track the sun and can be categorized into 3 large groups based on the method of control which are; closed loop, open-loop and hybrid. Generally, closed loop systems use photo sensors in its tracking system while open loop system involved a mathematical calculation of the sun's position without photo sensing. Hybrid, in the meantime, is the combination of both closed and open loop systems. The advantage of an open loop system compared to the closed loop system is; it is not dependant on the weather condition and can work independently despite of cloudy conditions where most of conventional closed-loop systems fail to work properly under non uniform insolation conditions [15]. Moreover, the drawback of a closed loop system is; it requires additional hardware and complex control systems and actuators. In this climate, where cloud formations are frequent, open loop system is more suitable thus power is not wasted in frequent movement of the actuator as a result of the photo sensors used. In the meantime, in comparison to closed-loop and hybrid system, open loop is chosen since it is more cost effective and well suited to this tropical climate.

Generally, the sun tracking system is categorized as a mechatronic system. A single axis sun-tracking system consists of one controlling motor with varying azimuth angle and a fixed-tilt angle, while a dual-axes sun-tracking system has two controlling motors varying in azimuth angle and altitude-angle of the sun. The dual axes are the best system in all weather conditions even in tropical regions [16]. In previous studies, single axis tracking was implemented in systems and simply put, minimized the power consumption yet improved the solar energy yield. One system uses discrete two-positional changes in azimuth angle in its tracking system [17], while, many others use either a closed-loop system or an open-loop system to control the movement of the motor [18–20].

A dual-axes tracking system, however, is more popular than the single-axis since it produces more energy. The application varies from photovoltaics (PV), solar collector and even to control the effective orientation of a pyrheliometer. Sungur designed an open loop PV system based on the calculation of the sun each hour of the day. The movement is divided into different time slices from



Yearly average value	Solar Radiation (kWh/m²)
Kuching	1470
Bandar Baru Bangi	1487
Kuala Lumpur	1571
Petaling Jaya	1571
Seremban	1572
Kuantan	1601
Johor Bahru	1625
Senai	1629
Kota Bahru	1705
Kuala Terengganu	1714
Ipoh	1739
Taiping	1768
Georgetown	1785
Bayan Lepas	1809
Kota Kinabalu	1900

Fig. 1. Solar radiation distributions in Malaysia [14].