Average photon energy under Thailand's climatic condition

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Abstract

This paper presents seasonal spectral solar irradiance distribution variation under Thailand's climate. The annual spectral solar irradiance distribution measurement at Energy Park, School of Renewable Energy Technology (SERT), Naresuan University, Thailand showed that the maximum frequencies of solar irradiations were in the ranges 420-710 W/m^2, i.e., blue rich range or visible light. The maximum frequencies of photon flux densities calculated were in the ranges 3.40x10^{17}–5.30x10^{17} photon/m^{2}s. The average photon energy (APE) values were found to be 1.92 eV, 1.90 eV and 1.84 eV in summer, rainy and winter seasons respectively. The annual spectral irradiance measurement data showed that APE of total incident solar irradiance was 50% higher than that of the AM 1.5 standard solar spectrums. These results indicate that the wavelength is influence of photon flux density.

Key Word: *Average photon energy, Photovoltaic*

1. Introduction

Climate change has caused variation in the world climate and has also made the differences of the sun rays in atmosphere. Photovoltaic technology converts solar energy into electricity. When photon of light strikes a solar cell, photo-electron is generated. The energy of photo-electron depends on the photon energy, which in turn depends upon the frequency or color of the light. The energy of visible light can adequately excite electrons up to higher energy levels creating more free electrons to move. The spectral responses of solar cell with the frequency of light differ according to type of solar cell (mono-crystalline, poly-crystalline or amorphous silicon). The spectrum distributions is an important to find the energy mean of photon that bumped with the solar cell. Due to the frequent has directly with the current that is produced from the solar cell, and has relation with the energy that is produced from the solar cell. The power of photo-electron is directly variation with frequency of photon. The spectral flux density is one of the important factors in finding the average photon energy (APE) that bumps with the solar cell. Due to that wavelength will be directly affected with the electricity that is produced from solar cell. In this paper, we present the measurement results of the annual spectral irradiance distribution at SERT.

2. Experimental

The annual spectral irradiance distribution was measured at SERT, Phitsanulok, Thailand (latitude 16^{o}49' N and longitude 100^{o}15' E). Spectral irradiance at the wavelength range of 350–1050 nm were recorded every 5 minutes by spectro-radiometer (MS720, EKO). The spectro-radiometer was tracked direct to the sun every hour. The characteristic were found useful for the spectral irradiance distribution with a simple and device-independent index, spectral flux density (Φ) is the quantity that describes the rate at which energy transferred by electromagnetic radiation is received from a source, per unit area facing the source, per unit wavelength range.

$$\Phi = \frac{\lambda \cdot E(\lambda)}{hc} \tag{1}$$

Where, $E(\lambda)$ is the spectral irradiation, λ is the wavelength, h is Planck's constant, and c is the speed of light, respectively.

Average photon energy (APE) is defined as the total irradiance contained in the spectrum divided by the total photon flux density [1, 2]. The APE of each spectrum is calculated from the wavelength range of 350–1050 nm of the measured spectrum. The APE value for the Am 1.5 standard solar spectrum calculated with 350-1050 nm wavelength range is 1.878 eV.

APE can also be defined as the integrated irradiance divided by the integrated flux density, which yields the average energy per photon [3]:

$$APE = \frac{\int_a^b E(\lambda)\,d\lambda}{q\int_a^b \Phi(\lambda)\,d\lambda} \quad (2)$$

Where, q is the electronic charge, E is the spectral irradiance, and Φ is the spectral photon flux density. In this study, a and b are set to 350nm and 1050 nm respectively.

3. Results and discussions

3.1 Relationship between solar irradiation and photon flux density.

Fig. 1 shows relationships between solar irradiation and photon flux density, with data collected from January to December 2008. The solar irradiation is calculated from the integrated spectral irradiance of each wavelength measured in the range 350-1050 nm. The maximum frequencies of solar irradiations were in the ranges 420-710 W/m^2, i.e., blue rich range or visible light. The maximum frequencies of photon flux densities calculated were in the ranges 3.40x10^{17}–5.30x10^{17} photon/m^{2}s. Solar irradiance is directly proportional with photon flux density. These results indicate that the wavelength is influence of photon flux density.

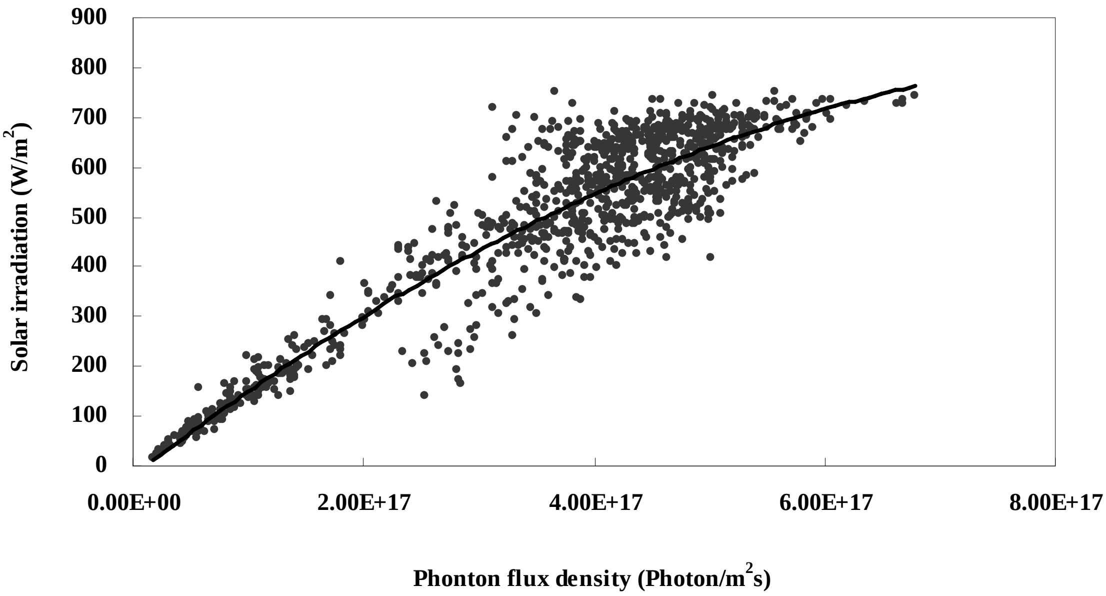

Fig.1. Variation of photon flux density on solar irradiation.

3.2 Seasonal variation for APE

Fig.2 shows monthly changes of spectral irradiance and it is used to calculate APE. The APE is calculated from the integrated solar irradiance of each wavelength for the month by the integrated photon flux density. The APE of total incident solar irradiance has 50% higher than 1.88 eV. The APE has higher than AM1.5 standard solar spectrum been obtained between April to October. The effect of solar spectrum in the each season of Thailand Climatic describes as following; summer season, the summer season starts from March until the end of June. This season, the North Pole is facing and the shortest distance to the Sun, is less amount of carbon dioxide in atmospheric because of there are a lot of plants used carbon dioxide for photolysis phenomenal . The solar spectrum is very little absorbed by the atmosphere. In other hand, the rainy season, there is a lot of the moisture content in the atmospheric. It is greatly absorbed solar spectrum than other seasons, so the solar spectrum is less than other seasons. And the winter season, the North Pole is far away from the sun. There is a lot of carbon dioxide in atmospheric but less amount of moisture content in the air, so solar spectrum is less absorbed compare to the rainy season.

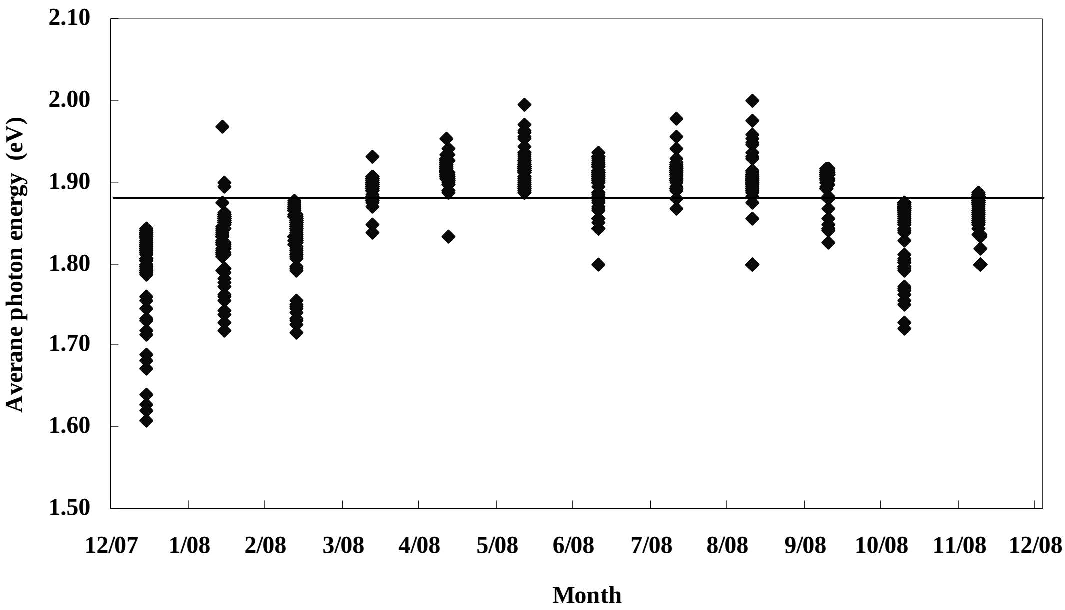

Fig.2. Annual average photon energy (APE) at Naresuan University in Thailand.

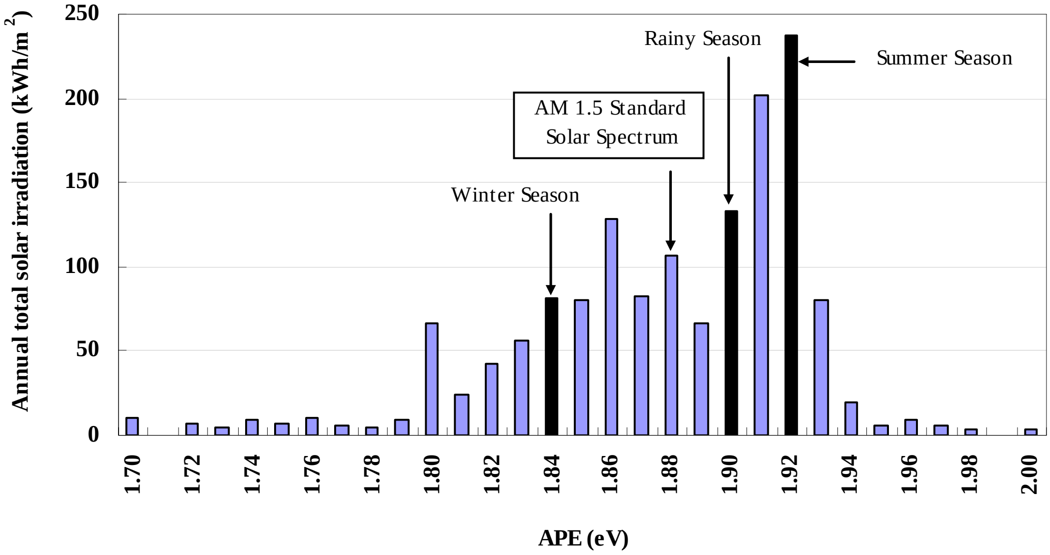

Fig.3. Seasonal variation for average photon energy (APE)

Fig.3 show average photon energy (APE) annual accumulated of solar irradiation. The annual spectral irradiance distribution was measured it is analyzed to find APE which it was found to be in the range 1.70-2.00 eV and the APE histogram of an annual total irradiance. The figures show disparity APE of each season which in summer season (March, April, May and June), the APE was high value at 1.99 eV, which is 0.11 eV higher than that of the AM1.5 standard solar spectrum 1.88 eV. In rainy season (July, August, September and October), the APE was high value at 2.00 eV, which is 0.12 eV higher than that of the AM1.5 standard solar spectrum and maximum rain was observed in July. In winter season (November, December, January and February), the APE was high value at 1.97 eV, which is 0.9 eV higher than that of the AM1.5 standard solar spectrum and fig. 4 show the examples of solar spectra with average APE of three seasons

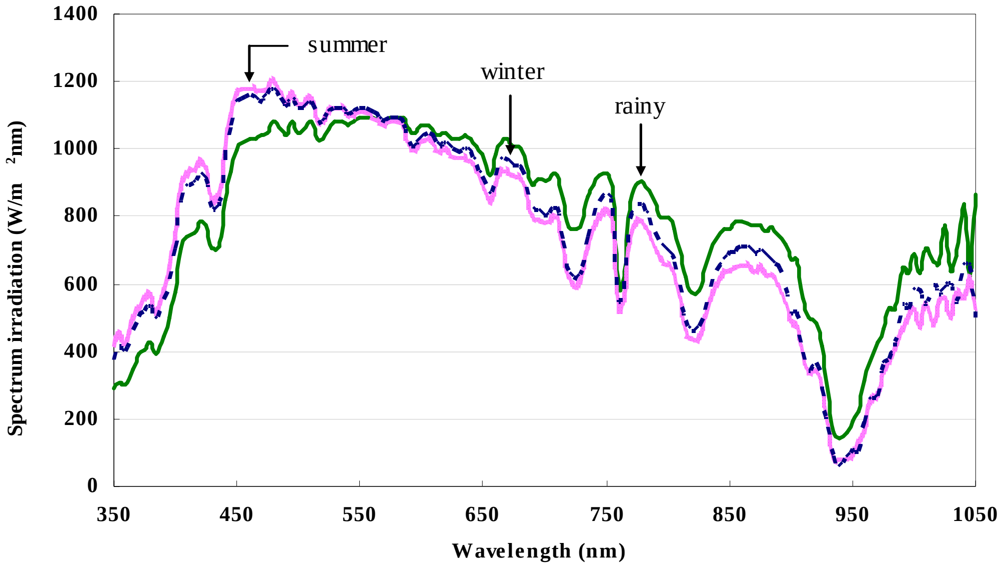

Fig.4. Examples of solar spectra with average APE of three seasons.

Fig.4 shows examples of solar spectra with average APE of three seasons which the solar irradiation is calculated from the integrated spectral irradiance of each wavelength measured in the range 350-1050 nm. Fig.4 shows spectrum irradiation in winter season at solar irradiation 550.7 W/m^2 and APE 1.84 eV, (b) Spectrum irradiation in rainy season at solar irradiation 529.4 W/m^2 and APE 1.90 eV and (c) Spectrum irradiation in summer season at solar irradiation 518.3 W/m^2 and APE 1.92 eV. The solar irradiation of three seasons are approximate to approach but it is be not related with APE. The APE is depends on spectral irradiance.

4. Conclusions

In conclusions, solar irradiation accumulated of annual which data corrected from January 2008 through December 2008. The maximum frequencies measured of solar irradiations obtained in the ranges 420-710 W/m^2, which this range is in blue rich or visible light and the maximum frequencies of photon flux densities calculated were also obtained in the ranges 3.40x10^{17} – 5.30x10^{17} photon/m^{2}s. Photon energy direct variation frequency of sun light. The average APE was 1.92 eV in summer, followed by 1.90 eV in rainy season, and 1.84 eV in winter season. The annual spectral irradiance measurement data showed that APE of total incident solar irradiance was 50% higher than that of the AM 1.5 standard solar spectrums. These results indicate that the wavelength is influence of photon flux density.

Acknowledgements

This research is a part of the Energy Park Project funded by the Energy Conservation Promotion Fund, the Energy Policy and Planning Office (EPPO), Thailand, and also supported by the Office of Research National Council of Thailand (NRCT). The authors are grateful to Kaneka Corporation, Japan, for supporting the research equipment and thankful to staff of SERT, Naresuan University, Thailand, for support in laboratory work. The study grant from Nakhon Sawan Rajabhat University is also duly acknowledged.

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