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Realization of Solar Sensing Device

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Abstract

In this paper, the solar sensing device used to measure the solar radiation whether it is same in all directions or maximum in the particular direction to convert it into the more electricity. The solar servo control tracking device using a pyranometer is disclosed. The device includes: a solar panel; a tracker having a solar panel driving motor driving the solar panel; a tracker controller controlling the tracker; first pyranometers measuring a solar azimuth in EW and detecting solar radiation of 380 nm to 840 nm wavelengths; second pyranometers measuring a solar azimuth in NS and detecting solar radiation; and a third pyranometer measuring a solar azimuth in the CE and detecting solar radiation. The tracker controller includes: signal amplifiers amplifying detection signals in three azimuths by the pyranometers; signal processors filtering the amplified detection signals by limiting a voltage; and a main control microcomputer outputting a control signal to the solar panel driving motor to stop the solar panel when the solar radiations are same and the solar radiations in one direction are maximum.

***Keywords**: Pyranometer, solar panel, tracker, solar azimuth, a signal processor, microcomputer.*

1. Introduction

In this paper, the solar servo control tracking device for a solar photovoltaic generation, and more particularly, the solar to a solar servo control tracking device using a pyranometer [1]. In general, solar light contains ultraviolet light of 3%, visible light of 43%, and infrared light of 54%. The wavelength with the highest energy density for solar photovoltaic generation is 380 nm to 780 nm of visible light and the wave of the next highest energy density is 840 nm of near infrared light wavelength of which is relatively short among infrared light. A solar cell (photovoltaic cell) performs energy conversion from sunlight to electric energy mainly using the wavelength of the visible light 380 nm to 780 nm and the wavelength of the near infrared light 840 nm. An existing device for detecting a sunlight incident angle is settled to measure the incident angle where solar radiation is maximized using a cadmium sulfide (CdS) light sensor. However, the detection of an incident angle of sunlight using the CdS light sensor has the following disadvantages. First, since only some of 380 nm to 450 nm (low band visible light) among wavelengths of 380 nm to 780 nm of visible light having high solar energy density is detectable and detection sensitivity becomes inferior due to non-linearity with respect to an incident angle of the sunlight, it is difficult to precisely detect sunlight. Since detection output is weak in cloudy or very changeable weather due to the detection output exhibiting a second order function characteristics, it is difficult to detect the precise

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incident angle of sunlight so that it is hard to improve the efficiency of solar photovoltaic generation. Second, since the detected incident angle of sunlight is restricted due to a triangular pyramid shape of the CdS light sensor, azimuth angles of sunlight with respect to east, west, south, and north cannot be detected. Due to this, two CdS light sensors are used. However, even in the case when the two CdS light sensors are used, it is difficult to track sunlight in the very changeable weather.

2. Construction Details of Pyranometer

The present invention has been made in view of the above problems, and it is an object of the present invention to provide a solar servo control tracking device using pyranometer for precisely detecting energy density of wavelengths of 380 nm to 840 nm that are required for solar photovoltaic generation using a plurality of pyranometers capable of measuring solar radiation in three directions such as east-west (EW), north-south (NS), and vertical center (CE) so as to measure an incident angle of sunlight with the highest energy density and to improve the efficiency of solar photovoltaic generation. In accordance with an aspect of the present invention, the above and other objects can be accomplished by the provision of a solar servo control tracking device using pyranometers as shown in

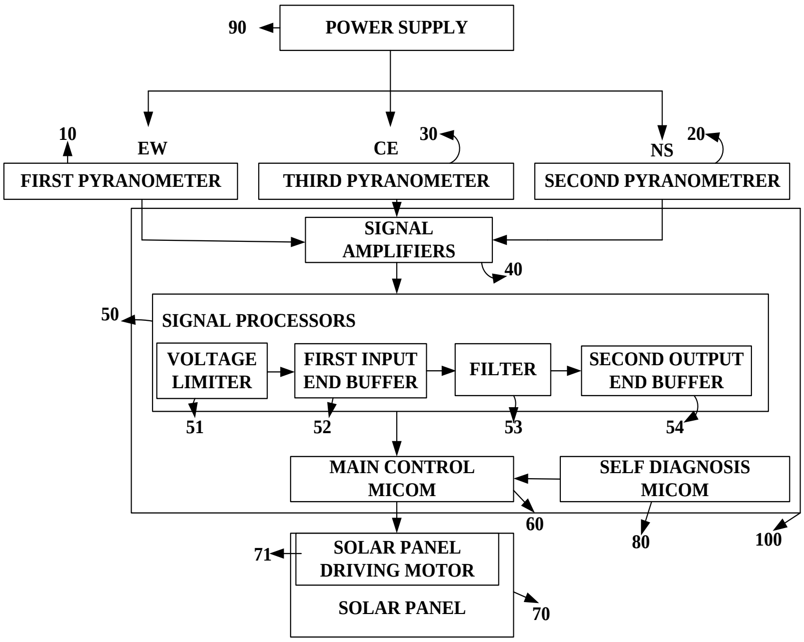


Figure 1. Block Diagram Illustrating a Solar Servo Control Tracking Device using Pyranometer

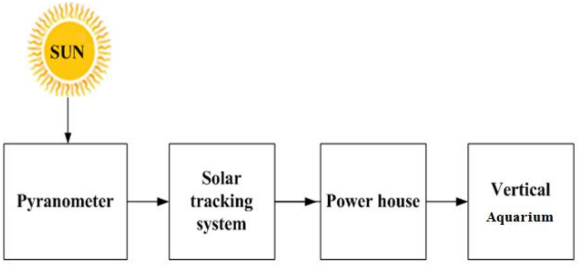


Figure 2. Block Diagram of Solar Generation System for Building an Aquarium

The Figure 1. The Pyranometer is used to detecting the best light or radiation for operating the solar tracking system. The pyranometer could measure the solar radiation from the sun and the amount of energy send to the Building Aquarium.The block diagram of solar generation system for building aquarium as shown in the Figure 2. The Figure 1 including: a solar panel (70); a tracker (200) including a solar panel driving motor (71) for driving the solar panel (71); a tracker controller (100) controlling the tracker (200); a plurality of first quadrangular or semi spherical pyranometers (10) measuring a solar azimuth in the east and west direction (EW) and detecting solar radiation of wavelengths of 380 nm to 840 nm; a plurality of second quadrangular or semispherical pyranometers (20) measuring a solar azimuth in the north and south direction (NS) and detecting solar radiation of wavelengths of 380 nm to 840 nm; and a third quadrangular or semi spherical pyranometer (30) as shown in the Figure 3. It measuring a solar azimuth in the vertical central direction (CE) and detecting solar radiation of wavelengths of 380 nm to 840 nm; where in the tracker controller (100) includes: a plurality of signal amplifiers (40) amplifying solar radiation detection signals in three azimuths of the east and west direction (EW), the north and south direction (NS), and the vertical central direction (CE), which are measured by the first, second, and third pyranometers (10, 20, and 30); a plurality of signal processors (50) filtering the three directional amplified solar radiation detection signals by limiting a voltage; and a main control microcomputer (60) outputting a control signal to the solar panel driving motor (71) such that the solar panel (70) is stopped when the solar radiations in a first direction or the solar radiations in a second direction among the plurality of output signals in three directions output from the signal processors (50) are same and the solar radiations in one direction are maximum. The first direction where the solar radiations are same is the east and west direction (EW), the second direction where the solar radiations are same is the north and south direction (NS), and the one direction where the solar radiation is maximum is the vertical central direction (CE). The solar servo control tracking device using pyranometers further includes a self-diagnosis microcomputer (80) monitoring whether the output control signal of the main control microcomputer (60) is abnormal and controlling the main control microcomputer (60) to be reset or standby when the output control signal is abnormal. The signal amplifiers output voltages with respect to the three directional solar radiations detected by the first, second, and third pyranometers (10, 20, and 30) as shown in the Figure 4 and using push-full amplifier transistors (Q1 to Q18) to the output current. The Signal processing unit as shown in the Figure 5 and each of the signal processors (50) includes: a voltage limiter (51) limiting the amplified signal of the first, second, and third pyranometers (10, 20, and 30) within 5V; a first input end buffer (52) buffering the voltage-limited amplified signal; a filter (53) filtering the buffered amplified signal; and a second output end buffer (54) buffering the filtered amplified signal to be output to the main control microcomputer (60)[2][3][4]. According to the present invention, energy density of wavelengths that is required for the solar photovoltaic generation can be precisely measured. Since output characteristics of the pyranometers exhibit linear log output characteristics with respect to the incident angle of sunlight, detection sensitivity is excellent to precisely detect sunlight. Due to the linear log output characteristics of the pyranometers, the incident angle of sunlight is easily detected in various weather conditions such as clear day as well as cloud weather so that efficiency of solar photovoltaic generation can be improved and sunlight can be rapidly tracked even in very changeable weather. In the Figure 3(b), semispherical pyranometer refers to the Figure 4. The Figure 4 is similar to the matrix. In the matrix 00 refers to Q5 transistor circuit and it indirectly refers to the Figure 3(b). It is center to the vertical and horizontal circuits of the pyranometer like that 10,11,12,13 refers to horizontally aligned.

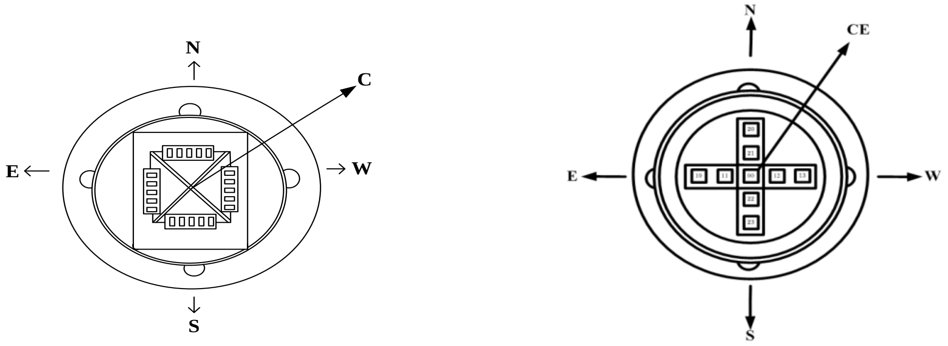


Figure 3. Plan View (a) Illustrating a Quadrangular Pyramid-Shaped, (b) Semispherical Pyranometer

Sensors and 20,21,22,23 refers to the vertically aligned sensors of the pyranometer. These sensors circuits as shown in the Figure 4. The matrix refers to the sensor circuit which is shown in the Figure 3(b). These sensors accurately determined the maximum sun radiation point and converts it into the maximum electrical energy. The tracking control of both axes (a rotation axis and an altitude axis) is performed using the first pyranometers 10 as pyranometers in the east and west direction EW, the second pyranometers 20 in the north and south direction NS, and third pyranometer 30 in the vertical central direction CE.The pyranometer exposed to outdoor operation will have a response voltage V usually expressed as follows:

$$V = R(\theta)\left(\mathrm{I}_{direct}\cos(\theta) + \mathrm{I}_{diffuse}\right) \tag{1}$$

With θ as the solar zenith angle, I_{direct} is the direct irradiance, $I_{diffuse}$ the diffuse irradiance collected by the dome of the pyranometer in the measured orientation and $R(\theta)$ the sensitivity coefficient as a function of the orientation angle of the tool relative to the sun with units of [V m^2 / W]. However, in laboratory conditions, diffuse irradiance source is avoided and the plane of the pyranometer and the pattern should be normal to the maximum intensity of the source. So that the voltage response of the pyranometer can be defined according to the following expression:

$$V = \int_0^b R(\theta_0)\mathrm{I}_{direct}F(r)dr = I_{direct}R(\theta_0)\left[\int_0^a F(r)dr + \int_a^b F(r)dr\right] \tag{2}$$

With I_{direct}, the maximum irradiance at the center point of the distribution. $F(r)$is the normalized spatial distribution function of the intensity. In this case the Pyroelectric detector area is circular with radius b larger than the electrically calibrated pyroelectric detector (ECPR) area with detector radius a.

The response of the standard is similar and according to the following expression:

$$I_{\text{standard}} = \int_0^a I_{direct} F(r) dr \tag{3}$$

The expressions (2) and (3) do not include any correction for spectral response because both sensors have a flat response in the visible and near infrared. From (2) and (3) the response of the pyranometer irradiance at normal incidence is:

$$\begin{aligned} R(\theta_0) &= \frac{V}{I_{direct}\left[\int_0^a F(r) dr - \int_a^b F(r_a - r_b) dr\right]} \\ &= \frac{V}{I_{\text{standard}} - I_{direct}\int_a^b F(r_a - r_b) dr} \end{aligned} \tag{4}$$

The determination of the irradiance on the plane of the detectors is based on the premise of having the same normal distance from the source to each of the planes of the detectors, which can be secured by the mechanical alignment of the edges of dome external reference of the pyranometer and known reference pyroelectric plane [9].

3. Design of Sensor Signal Processing Circuits

A solar servo control tracking device using a pyranometer according to an embodiment of the present invention, as illustrated in Figure 6(b), includes solar panels 70, a tracker 200 having a solar panel driving motor 71 rotating the solar panels 70; and a tracker controller 100 controlling the tracker 200.The tracker 200 is installed between a plurality of the solar panels 70 and includes, as illustrated in Figure 6(b), the solar panel driving motor 71, a first reduction gear 72, a second worm reduction gear 73, a third worm reduction gear 74, and an azimuth sensor unit 75.

The solar panel driving motor 71 is driven by a servo control of the tracker controller 100. To the solar panel driving motor 71, the first reduction gear 72, the second worm reduction gear 73, and the third worm reduction gear 74 are sequentially connected to generate high torque required to drive the solar panels 70 that is transmitted to the solar panels 70 such that a pinion of the third worm reduction gear 74 is connected to the second worm reduction gear 73 and sequentially a worm wheel of the third worm reduction gear 73 is connected to a pinion of the third worm reduction gear 73 so as to generate maximum driving torque. A solar panel fixing shaft 76 to which the solar panels 70 are fixed is installed to the worm wheel. The azimuth sensor unit 75 is installed to the tracker 200 to detect an absolute azimuth of the solar panels 70 for the rotation angle servo control of the solar panels 70. The azimuth sensor unit 75 includes a sensor pinion, a sensor worm wheel, and an azimuth sensor. The sensor pinion is connected to the pinion of the third worm reduction gear 74, the sensor worm wheel is connected to the sensor pinion, and the azimuth sensor is installed to a rotation shaft of the sensor worm wheel. The azimuth of the solar panels 70 detected by the azimuth sensor is transmitted to the tracker controller 100. Meanwhile, the tracker controller 100 may include a wind speed sensor 300 outputting a wind speed signal to the tracker controller 100 (Figure 6(a)) and a limit switch (not shown) limiting the rotation angel of the solar panels 70 within a predetermined angle to prevent the solar panels 70 from being damaged such that the tracker controller 100 controls the solar panels 70 to be parallel to the ground when a typhoon or a strong wind occurs. The wind speed sensor 300 protects the solar panels 70 in nasty weather such as a typhoon or a strong wind. The wind speed sensor 300 detects a wind speed and outputs the wind speed to the tracker controller 100 when the typhoon or the strong wind occurs, and the tracker controller 100 outputs a control signal to the solar panel driving motor 71 to control the solar panel is parallel to the ground.

$$\begin{bmatrix} 13 & 23 \\ 12 & 22 \\ 11 & 21 \\ 10 & 20 \\ \multicolumn{2}{c}{00} \end{bmatrix}$$

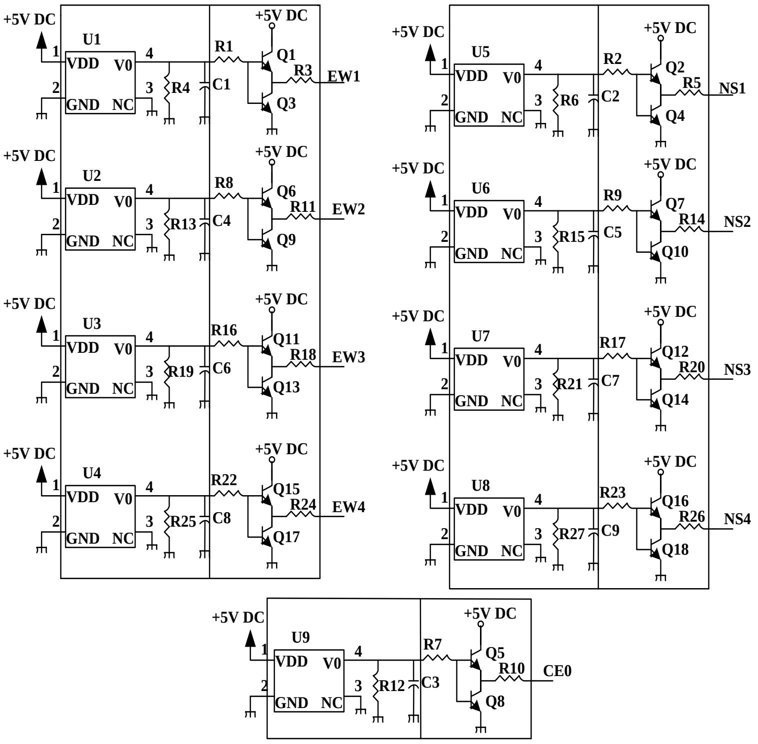
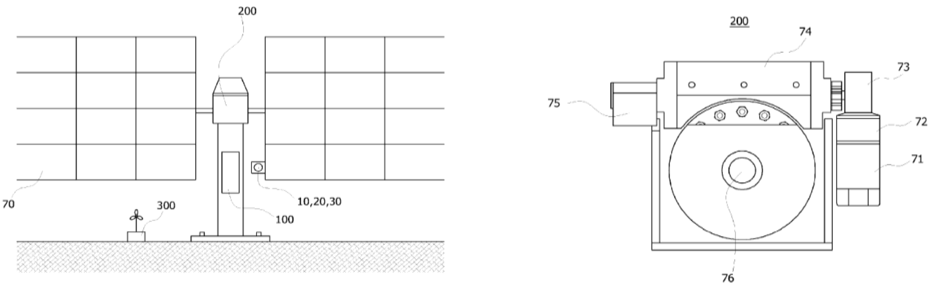


Figure 4. A Circuit Diagram Illustrating First, Second and Third Pyranometers and a Signal Amplifier



(a) (b)

Figure 6. (a) A Schematic View Illustrating the Solar Servo Control Tracking Device According to the Embodiment of the Present Invention,(b) Illustrating a Tracker of the Solar Servo Control Tracking Device according to the Embodiment of the Present Invention

In the above-mentioned solar servo control tracking device, the tracker controller 100 includes pyranometers 10, 20, and 30, a plurality of signal amplifiers 40, a plurality of signal processors 50, the main control microcomputer 60, and a self-diagnosis microcomputer 80. The pyranometers 10, 20, and 30, as illustrated in Figure 6(a), may be installed to sides of the solar panels 70 or at other positions. Hereinafter, driving of the solar panels 70 by the tracker 200 will be described using the solar panel driving motor 71 and the control of the tracker 200 by the tracker controller 100 will be described using the plurality of signal amplifiers 40, the plurality of signal processors 50, the main control microcomputer 60, and the self-diagnosis microcomputer 80. The solar servo control tracking device using a pyranometer according to the embodiment of the present invention, as illustrated in Figure 1, includes a plurality of first, second, and third pyranometers 10, 20, and 30, the plurality of signal amplifiers 40, the plurality of signal processors 50, and the main control microcomputer 60.

The plurality of first, second, and third pyranometers 10, 20, and 30, as illustrated in Figure 3, has a quadrangular pyramid shape (an upper drawing in Figure 3) or a semispherical shape (a lower drawing in Figure 3), and detects solar radiation of wavelengths of 380 nm to 840 nm that is required for the solar photovoltaic generation in the east and west direction EW, in the north and south direction NS, and in the vertical central direction CE.

The plurality of first pyranometers 10 measures a solar azimuth in the east and west direction EW (bank angle), the plurality of second pyranometers 20 measures a solar azimuth in the north and south direction NS (solar altitude), one third pyranometer 30 measures solar azimuth in the vertical central direction CE (vertical angle) so as to measure an incident angle of sunlight with the highest energy density of wavelengths of 380 nm to 840 nm at the corresponding solar azimuth. In Figure 3, the plurality of first pyranometers 10 are indicated by U1 to U4, the plurality of second pyranometers 20 are indicated by U5 to U8, and the third pyranometer 30 is indicated by U9. Solar radiations measured by the plurality of first, second, and third pyranometers 10, 20, and 30 are output as a voltage by resistors R4 and a capacitor C1 that are connected to each other in parallel in a case when the first pyranometer 10 is U1. Since output characteristics of the pyranometers with respect to the incident angle of sunlight exhibit a linear log output response, sunlight can be precisely detected regardless of weather change such as cloudy or fine weather. The plurality of signal amplifiers 40 amplifies solar radiation detection signals in the three solar azimuths of the east and west direction EW, the north and south direction NS, and the vertical central direction CE that is measured by the plurality of first, second, and third pyarnometers 10, 20, and 30 in the east and west direction EW, the north and south direction NS, and the vertical central direction CE such that output voltages of the three directional solar radiations that are measured by the first, second, and third pyranometers 10, 20, and 30 are amplified by push-full amplifier transistors Q1 to Q18 (Figure 4) and are output as current. Among the push-full amplifier transistors Q1 to Q18 of Figure 4, Q1 and Q3 are assigned to push-full amplifier transistors of one U1 of the first pyranometers 10. Each of the signal processors 50 includes a voltage limiter 51 filtering the respective amplified three directional detection signals by limiting voltage and outputting the voltage-limited detection signals to the main control microcomputer 60, a first input end buffer 52, a filter 53, and a second output end buffer 54. The voltage limiter 51 is a circuit device for limiting the respective amplified signals of the first, second, and third pyranometers 10, 20, and 30 within 5V, and for example, an amplified signal from the first U1 of Figure 4 is limited within 5V by a resistor R3, a capacitor C3, and a Zener diode D1 as illustrated in Figure5. The first input end buffer 52 is a circuit device for buffering the amplified signal limited within 5V, for example, a comparator U1A connected to the resistor R3, the capacitor C3, and the Zener diode D1 of Figure 5. The filter 53 is a circuit device filtering the amplified signal buffered by the first input end buffer 52, and filters the amplified signals using a resistor R4 and a capacitor C4 as a first low- pass filter that is connected to the comparator of Figure 5.The second output end buffer 54 is a circuit device buffering the filtered amplified signals and outputting the buffered amplified signals to the main control microcomputer 60, for example, a comparator U1B connected to the resistor R4 and the capacitor C4 of Figure 5.

The main control microcomputer 60 outputs a control signal to the solar panel driving motor 71 such that the solar panels 70 are stopped when the output signals from the signal processors 50 in one direction, that is, the east and west direction EW or in two directions of the east and west direction EW and the north and south direction have the same value and an output signal in one direction, that is, the vertical central direction CE is maximum. A constant voltage is applied to the first, second, and third pyranometers 10, 20, and 30 to drive the sensors by a power supply 90.The solar servo control tracking device according to the embodiment of the present invention further includes the self-diagnosis microcomputer 80. The self-diagnosis microcomputer 80 diagnoses the main control microcomputer 60 when there occurs a trouble in controlling the solar panels 70 despite the main control microcomputer 60 outputs the control signal for driving the solar panels 70, and controls the main control microcomputer 60 to be reset or standby such that maintenance is enabled by an operator when an abnormal operation of the main control microcomputer 60 such as a control error of the output control signal is diagnosed.

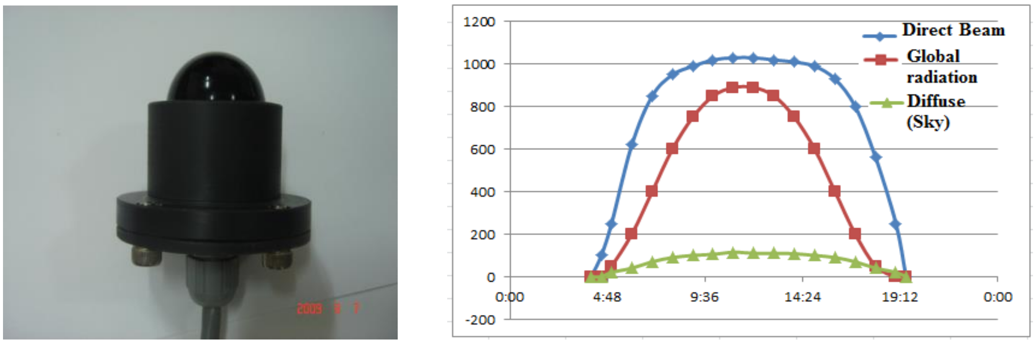
The above-mentioned solar servo control tracking device using a pyranometer has operating modes such as a manual mode and an automatic mode performed by an input switch (not shown).In the automatic mode, the solar panels 70 automatically track sunlight due to the control signal from the main control microcomputer 60 in accordance with the measured signal by the first, second, and third pyranometers 10, 20, and 30. In cloudy weather, when the measured values of the pyranometers 10, 20, and 30 are lower than a preset reference value, the main control microcomputer 60 controls using a timer (not shown) the solar panels 70 to automatically track sunlight by a solar incident calculation program with respect a time function. Thus, the incident of sunlight is easily detected in various weather conditions from fine day to cloudy day [5] [6].

In the automatic mode, the main control microcomputer 60 outputs a control signal to the solar panel driving motor 71 to drive the solar panels 70 in the east and west direction EW such that solar radiations of the plurality of first pyranometers 10 are same and to stop the solar panels 70 at a point where the solar radiation from one of the third pyranometers 20 in the vertical central direction CE is maximum. As such, a short axis (rotation axis) tracking control is performed using the first pyranometers 10, that is, the plurality of pyranometers in the east and west direction EW and the third pyranometer 20, that is, the one pyranometer in the vertical central direction CE.

Moreover, the main control microcomputer 60 outputs the control signal to the solar panel driving motor 71 to drive the solar panels 70 in the east and west direction EW such that solar radiations output from the plurality of first pyranometers 10 are same, to drive the solar panels 70 in the north and south direction NS such that solar radiations output from the plurality of second pyranometers 20 are same, and to stop the solar panels 70 at the point where solar radiation output from the third pyranometer 30 in the vertical central direction CE is maximum[1].

4. Experimental Results

The output characteristics of the pyranometers with respect to the incident angle of sunlight exhibit a linear log output response, sunlight can be precisely detected regardless of weather change such as cloudy or fine weather. The tracking control of both axes (a rotation axis and an altitude axis) is performed using the first pyranometers 10 as pyranometers in the east and west direction EW, the second pyranometers 20 in the north and south direction NS, and third pyranometer 30 in the vertical central direction CE. The pyranometer sensor has been shown in the Figure 7(a). The testing and analysis of the pyrometer have been satisfied. The characteristics of pyrometer have shown in the Figure 7(b). On the x-axis taken as Mountain Standard Time and y-axis represents irradiance watts/square meter. The blue color curve indicates the direct beam radiance of the sun, brown color curve indicates the total radiation of the sun and yellow green color curve indicates the diffusion radiation of the sun.



(a) (b)

Figure 7. (a) Pyranometer Sensor, (b) Solar Irradiation Measurement by Pyranometer (x- axis Represents Mountain Standard Time and Y-axis Represents Irradiance Watts/Square Meter

5. Conclusion

In this paper, the measuring device is designed for the solar generation system to the building aquarium. From the result, it can be concluded that the precise operating angle servo-control is implemented by using operating angle sensor unit. The each of the tracking device controllers receives an optimal signal from the integrated control panel to perform the precise operating angle servo-control and hence the efficiency of the pyranometer has been satisfied.

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