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Cost Effective Pyrheliometer for Solar Radiation Measurement

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Abstract

This paper aims to make a pyrheliometer calculating the amount of direct solar radiation from which the solar panels can achieve maximum efficiency. In terms of cost this paper overcomes the current pyranometer device by neglecting the different sensors. To calculate the amount of solar radiation, the proposed device incorporates an aluminium disc and a thermocouple. The thermocouple sensor produces a signal of voltage output which is proportional to the solar irradiance. The analogue thermocouple voltage is transformed to a digital signal by means of a 10-bit A / D high-end converter. Then, the thermocouple's electrical signal is amplified and measured as Watt / m2 over a monitor. This project also gets and stores the data through Arduino Atmega in real time. Thus, the amount of solar radiation in a given area can be determined by using the pyrheliometer and the solar panels can be properly positioned in that area for better performance. These types of meters are commonly used in meteorology, research into climate change, research into building engineering and much more.

Keywords: *Thermocouple, Pyrheliometer, pyranometer, solar radiation measurement.*

1. Introduction

During this busy present time energy could be a much needed one nowadays. Many sources feed this energy; one of the most common sources is the source of solar energy. The solar power derivation will lift the entire planet up. An enormous amount of power can be produced by properly implementing the solar panels over the sphere in proportion to the value [1]-[2]. Solar panels shall be installed where there is full sunlight coverage.

In the planet, there are several methods by which maximum solar radiation can be calculated [3]. These types of meters are commonly used by climate and weather scientists to track the amount of radiations that reach the earth at a selected location and time. Pyrheliometers can be used to measure the intensity of the radiation in Watts per unit area (Wm2). Trained pyrheliometers and pyranometers are highly costly and delicate [4]. Pyranometer and pyrheliometer are two devices used to measure irradiance from the solar system. Both are similar in purpose, although they have variations in principle of design and dealing [5]-[6].

Pyrheliometer is an instrument that calculates the irradiance of the direct sun and is distinct from Pyranometer where it calculates diffused radiation from the sun and not direct light. Both the meters transform the energy from the sun into an electrical signal that can easily be calculated.

2. Proposed System

The system proposed greatly reduces the expense of the current system and stores the data in real time. The current pyranometer uses a sensor that detects the radiation from the incident and gives the output. In the proposed device the thermocouple and aluminium disc replace the sensor. At first, the aluminium disc absorbs direct ray sunlight. The aluminium disc on one side is black in colour, on the other side white. It coats the black colour to absorb the full radiation [7]. The aluminium disc heats up to the solar radiation absorbed by it. The thermocouple positioned behind the aluminium disc senses the difference in temperature and yields the output. When there are more Temperature disparity, the show would have a Watt / m2 greater. This output value gives the amount of power to be produced in that area.

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The proposed system also includes an Arduino atmega panel, rectifier, Laptop and LCD monitor. The Arduino atmega is fed sensed radiation from the pyrheliometer. Arduino atmega's necessary operating voltage is 5 V, DC supply is fed from the rectifier, which is connected to the 230 V, AC supply. In the LCD monitor the output radiation value will be displaced. This meter tests the direct sunlight radiation falling at 90 ° upon the earth. The amount of power which can be produced in this area is measured in Watts / m2 by measuring the direct incident light.

The light from Sun is allowed to enter the instrument and is then transmitted to a thermocouple which converts this energy into electrical signals [8]. The voltage generated tells the watts of the energy received per area unit. Pyrheliometer helps to determine the performance of solar panels mounted to harness the energy of the sun and also aid in meteorological research

A. Design of thermocouple pyrheliometers

A thermocouple pyrheliometer is built with thermocouple sensor and glass dome to achieve the proper directional and spectral characteristics. A black-coated thermocouple sensor which absorbs all of the solar radiation. A flat spectrum covering the range from 300 to 50,000 nanometers and has an almost perfect response to cosine. A glass dome, while preserving the 180 ° field of view, limits the spectral response from 300 to 2.800 nanometers (cutting off the part above 2.800 nm. It also shields the sensor from convection by thermocouples. A second glass dome is used for premium and secondary standard pyrheliometers. This building adds to that radiation shield that results in a better thermal balance between the sensor and the inner dome compared to a single dome. The effect of having a second dome is a marked decrease in instrument offsets.

The active (hot) thermocouple junctions are located beneath the surface of the black coating and are heated by the radiation absorbed from the black coating. The thermocouple’s passive (cold) junctions are fully protected against solar radiation and in thermal contact with the pyrheliometer housing, which functions as a heat-sink [3]. This avoids any yellowing or deterioration alterations when measuring the temperature in the shade, thereby impairing the calculation of the solar irradiance.

The thermocouple produces a small voltage in relation to the difference in temperature between the surface of the black coating and the unit housing. This is in 10 μVW/m2 order. Usually the performance is about 10 mV on a sunny day. Pyrheliometer possesses a peculiar sensitivity, unless otherwise fitted with signal calibration electronics [5].

B. Design Components of the Proposed Pyrheliometer

The construction of the proposed Pyrheliometer consists of aluminum plate , glare-shield, Styrofoam, and mutlitmeter interfacing.

1. Aluminium Disc

In this project aluminium disc serves as the heat-absorbing feature. In hard disc drives and discs used in many other items and production processes, aluminium core discs are used for the "plattens".

2. PVC pipe (Glare-shield)

A mask of Glare is used to eliminate the indirect sunlight and only transfer direct sunlight to the disc's center point.

3. Thermocouple

Temperature is measured using a thermocouple. Thermocouple consists of two legs of wire constructed from various metals. At one end the wire legs are welded together forming a junction. This is the junction where we calculate the temperature. When a temperature change is observed at the junction a voltage is produced.

4. Styrofoam

Styrofoam is a heat insulation medium to avoid heat loss. It is used as thermal insulation and barrier to the water in walls, roofs and foundations.

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5. Hardware Setup

Fig.1 Finished Model

C. Arduio Coding

The calculation of solar radiation by IDE coding on the Arduino atmega controller using the proposed method in Arduino as shown below.

```
#include <Wire.h>//sensor library
#include <LiquidCrystal_I2C.h> //LCD library
#define BH1750_Addr 0x23 //Sensor address
byte buff[2]; // buffer for digital data storage
float Radiation;
LiquidCrystal_I2C lcd(0x27, 16, 2); //LCD configuration
void setup()
{
Wire.begin(); //sensor initialization
lcd.begin(16,2); //LCD initialization
lcd.backlight();
}
void loop()
{
uint16_tval = 0;
BH1750_Init(BH1750_Addr); //function call for sensor initialization
delay(200); // in millisecond
if(BH1750_Read(BH1750_Addr) == 2) // intensity in lux
{
val = ((buff[0]<<8) | (buff[1]))/1.2;
}
Radiation = (val * 0.04726); // 0.04726 = (max watt per meter sq / max raw )
lcd.setCursor(0,0); //1st column and 1st row
lcd.print("Radiation:"); // print on lcd
lcd.setCursor(0,1); //1st column and 2st row
lcd.print(Radiation); // print reading
lcd.print(" W/m^2"); //print unit
}
int BH1750_Init(int address)
{
Wire.beginTransmission(address);
Wire.write(0x10); // 1 1ux resolution 120ms
Wire.endTransmission();
```


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```
}
int BH1750_Read(intaddr)
{
intidx = 0;
Wire.beginTransmission(addr);
Wire.requestFrom(addr, 2); //request data from sensor
while(Wire.available()) //if data available
{
buff[idx] = Wire.read();
idx++;
}
Wire.endTransmission();
return idx;
}
```

3. Results and Discussions

Table 1 shows a comparison of the radiation measurement with different parameters. Measurement of solar irradiation done on a particular day from 9.00 am to 6.00 pm.

Table 1. Comparison of solar radiation measurements

Specifications	Proposed Thermocouple Pyrheliometer	Photodiode	Photovoltaic Pyranometer
Component used	Thermocouple	Photodiode	PV Cell
Sensitivity Range	300nm to 2800nm	400nm to 900nm	350nm to 1150nm
Cost	Less	Reliable	Moderate
Accuracy	Highest	Moderate	High

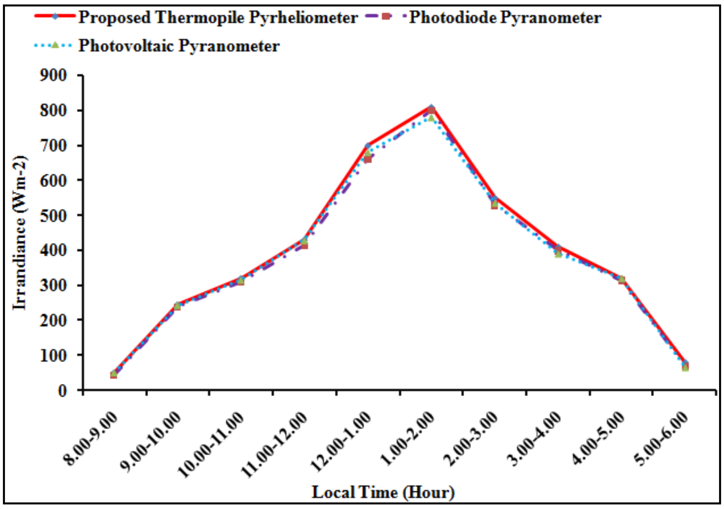

Fig.2 Solar radiation measurement result

The results tested are compared to the photodiode and photovoltaic pyranometer test as shown in graph. The designed Pyrheliometer Thermocouple gives better measurement compared with Pyranometer from the results.

4. Conclusion

The proposed thermocouple based Pyrheliometer is the most suitable device that can be used for developing countries to measure solar radiation. The use of thermocouple and microcontroller as main components makes it very easy to make solar radiation measuring device. The cost of maintenance is low and the overall cost of making the device is low, too. Therefore, the proposed device for measuring solar radiation is very effective by taking into account all parameters such as cost,

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reliability, Accessibility and Effectiveness. It helps find the best place or location to get the maximum solar radiation for more power generation.

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