Optimization of sensor model for solar radiation measurement with a pyranometer

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Abstract. Solar energy is electromagnetic energy produced in a thermonuclear process by the Sun from the nuclear fusion of the Sun's core. This process produces solar radiation. In the lives of living beings on this Earth, solar radiation plays a significant role. As mentioned earlier, the uses are when there is a certain level required for the solar radiation received and vice versa. A more specific measurement of solar radiation is, therefore, needed. Unfortunately, until now, measurement equipment for solar radiation was limited to a few parameters that could be observed. On the other hand, conventional mechanisms and communication media are still used in the current measurement monitoring system, so that the monitoring and analysis process is ineffective. Therefore, this paper provides a solar radiation sensor model that uses only a sensor but can produce four parameters. The system contains a Pyranometer and a real-time controller that can generate all of the solar radiation measurements needed. The proposed model system is hoped that this sensor system will work more accessible and more efficiently.

1. Introduction
Solar energy is a thermonuclear process that generates electromagnetic energy from the nuclear fusion sun in the Sun's core [1]. This process is produced by solar radiation. Solar radiation plays an essential role in the life of living things on Earth. There are many uses of solar radiation, from providing light rays during the day, a source of energy in the process of plant photosynthesis, to helping with the drying process of certain materials in industry and food. So, it will become health support for the human body or an alternative source of human energy in the future [2][3]. The uses mentioned above are when the received sun rays have a certain required level. On the other hand, if the radiation exceeds the required level, there will be losses, damage and even disasters. More specific measurements of solar radiation are therefore needed [4][5].

A large number of stations worldwide have measured solar radiation for many years [6][7]. In these measurements, weather forecasting was the primary purpose. In agriculture, for the prediction of harvesting dates and the issuance of irrigation advice, for the prediction of snow-flared and evaporative losses from tanks, in the construction industry, for the project of heating, air conditioning and illumination, the solar data were also used for other practicable applications [8][9]. The available data are mainly on the irradiance of the Solar and sky on the horizontal surface [10-12].

Various types of radiation measuring, such as Direct Radiation, Broadcast Radiation and Global Radiation, are available [11-14]. In addition, three consequential types of solar measuring instruments exist Pyrheliometer, Pyranometer and Photoclectric sunshine recorder, respectively, that special measure measurement [15-17]. Unfortunately, it requires all devices respectively to receive all the important radiation measurement data [18-20]. A special approach is, therefore, necessary to obtain the required data with a minimum device.
This paper, therefore, seeks to develop an integrated model for solar radiation measurements. The model can measure the required four parameters using a single sensor, that is, a Pyranometer sensor. The sensor is changed, so the accuracy of four solar radiation parameters can be increased, and the measurement results can simultaneously be displayed in a real-time monitoring system. A monitoring system will also be used as a display with a web system in order to monitor measurement results on a smartphone or notebook medium more easily. By adding an automatic shading device system and sun tracking system to work based on the measurement of the location coordinate, measurement performance will be optimized.

2. Solar Energy
We will look at various ways of using the energy of the Sun during these days to make use of this vast resource for the benefit of humanity. Our attention will be drawn to a wide range of applications, including house heating and cooling, megawatt power plants, crop drying and water distillation, giant solar ovens, small, doped and solar cell wafer applications, and multiple billion-dollar solar panels in the room. In the beginning, we can only naturally ask how much this resource, the solar energy, is available to us and how we measure it at a given time and site [6][15]. The application of solar energy is illustrated in figure 1.

![Solar power solutions](image)

**Figure 1.** Illustration of Solar Energy Application.

The energy crisis, on the other hand, suddenly appeared on the horizon. The increasing cost and declining supply of fossil fuels, long lines in petrol plants and the risk of power black-outs in homes and factories have made it clear to the industry that the prods of geological-stored fuel can't last long. Yet solar radiation is the only non-polluting form of energy [21]. Photons can be transformed into energy beneficial for humans without the thermodynamic series and polluting wastes. Whilst solar energy is received by the Earth-atmosphere system at the incredible rate of 5.4 to 1024j a year, the world's production of power is 27.000fold. A large, cost-free and inexhaustive supply of solar energy. It is spread slenderly and is highly variable over a broad area. These systems, however are high cost to build and maintain; they have to be financially competitive. If the systems for the existing solar power supply are not constructed, either the required energy is not supplied or the cost of capital is unnecessary [22].

Insolation is therefore a key parameter of the design. It is also required to evaluate competitive systems. One of the two aspects for calculating the proficiency of a system is solar energy input. For large-scale conversion systems, insulation data is required, such as megawatt power stations and high-temperature solar furnaces. High-radiance sites, small cloud coverage, a few days of nonstop cloud duration, must be selected for these sites. As solar energy is widespread, the spreading of conversion systems in which the energy is used has many advantages. For a range of applications, data on sub-regional to microclimate scale insulation should be provided. Heating, air conditioning, cooling and ice-making, desalination and crop-drying, solar and local hot water cooking, water motors, rural radio transceivers are some applications [2-5] [23] [24].
3. Solar Radiation and Measurements

Natural radiation is present to us as well as the characterization and measurement of radiation. The sun emitting and the Earth intercepting a fraction of the energy flow are categorized by the solar constant. Solar constants are essentially definite as solar flux density measurements per unit time, perpendicular to the Radiation Directive. Satellites outside the Earth's atmosphere are most precisely measured. The solar constant is currently predicted at 1367 W/m² [25] [26]. In fact, this number varies by 3% due to the Earth's elliptical orbit, with the distance from the Sun varying throughout the year. There is also a minor variation in the solar constant due to variations in the sun's brightness. This includes all kinds of radiation, a significant segment of which is lost when light permits through the atmosphere.

Solar radiation is dispersed or reflected by the atmosphere. All these courses reduce the density of energy streams. In fact, the solar flux density in the sun on a sunny day was reduced by about 30 per cent compared to extraneous radiation and by up to 90 per cent on a cloudy day. The following major losses should be calculated:

- Absorbed by atmospheric particles and molecules-10-30%;
- Mirrored and scattered back into space-2-11 percent
- Dispersed to Earth (Direct Radiation becomes diffuse)-5-26% [25]

As a result, direct radiation achieving the surface of the earth (or a device fitted on the surface of the earth) never more than 83% of the original extraterrestrial energy flow. The radiation, which comes straight from the solar disk, is defined as beam radiation or direct radiation (E). The scattered and reflected radiation that is directed to the surface of the earth from all directions (reflected from other bodies, molecules, particles, droplets, etc. is defined as Diffuse Radiation. The summation of the direct and diffuse components is defined as Total Radiation or Global Radiation. This relationship is shown in (1) [27].

\[ Eg\downarrow = E \cos \alpha + Ed\downarrow \] (1)

Where \( \alpha \) there is a zenith angle, the angle among the incident radius and the normal to the horizontal instrument flat. The wavelengths of solar radiation to be observed are classified in table 1. The alien solar spectrum is presented in figure 2. Figure 3 shows different radiation types on the Earth's surface.

Table 1 shows several solar radiation wavelengths. Short-wave radiation is the first thing. Direct sunshine is the wavelength range of 0.3 to 3 μm short-wave radiation. The components are both direct and diffuse. Long-wave radiation of 3 μm or longer wavelength is also produced from near-environmental sources of temperature-atmosphere, light collectors, earth's surface, other bodies [28].

| Solar Radiation Wavelength | Short-wave radiation | All of them are absorbed by the atmosphere before reaching the Earth |
|---------------------------|----------------------|---------------------------------------------------------------|
| UV-C                      | 200-280 nm           | All of them are absorbed by the atmosphere before reaching the Earth |
| UV-B                      | 280-315 nm           | 90 percent absorbed by the atmosphere |
| UV-A                      | 315-400 nm           | To the surface of the Earth |
| Visible Light             | 400-700 nm           | Visible light from purple to red |
| Near-Infrared             | 700 – 3000 nm        | Radiation from the Sun |
| Long-wave radiation       | Far Infrared         | Radiation from the atmosphere, Earth's clouds, and other objects |
|                           | 3000 – 50000 nm      | Radiation from the atmosphere, Earth's clouds, and other objects |
The solar radiation achieving the Earth is highly inconstant and depends on the state of the atmosphere at a precise location. Two atmospheric courses may be significantly affected by the happening irradiation: scattering and absorption. Scatter is caused by radiation interactions with airborne molecules, water, and dust particles. How much light is dispersed be subject to on the amount of particles in the atmosphere, the size of the particles, and the total mass of air through which the radiation is produced? Absorption occurs when radiation interacts with specific molecules, such as ozone, water vapor, and carbon dioxide (long-wave radiation absorption-infrared). Due to these processes, only a small portion of the entire spectrum of solar radiation reaches the Earth's surface. As a result, most x-rays and other short-wave radiation are captivated by atmospheric components in the ionosphere, ozone is absorbed by ultraviolet, and CO2 is absorbed by not-so-abundant long-wave radiation. As a consequence, the main wavelength range to be considered for solar implementation ranges from 0.29 to 2.5 μm [29]. The evidence of these facts is shown in figure 4.
The quantity of solar radiation on Earth's surface can be measured instrumentally, and accurate devices are important for the provision of background solar data for solar energy conversion implementations. Pyrheliometer, Pyranometer and Photoelectric Sunshine Recorders are three major kinds of devices used to measure solar radiation.

The Pyrheliometer is used to measure the normal incidence of direct beam radiation. There are different types of Pyrheliometer available. The Pyrheliometer is a common tool widely used, according to Duffie and Beckman [29]. The instrument measures the Direct Radiation coming from the Sun and a minor portion of the Sun's sky, based on its design. The involvement of the circumsolar sky to the beam is relatively insignificant on a sunny day with clear skies, based on experimental studies involving different designs of the Pyrheliometer. The hazy sky or the uniform thin cloud cover, however, redistributes the radiation so that the influence of the circumsolar sky to the measurement can become extra important.

The Pyranometer is conducted on a horizontal surface to measure total hemispheric radiation-direct plus diffuse. The Pyranometer measures Diffuse Radiation if it is shaded. The majority of solar resource data comes from the Pyranometers. The entire radiance (W/m²) measured by the pyranometer on the horizontal surface shall be expressed as (1). Pyranometers are also used on inclined surfaces to measure solar radiation, which is significant for collectors to estimate inputs. The calibration of the Pyranometers be subject to on the angle of inclination, so the measurements need real data to be interpreted.

The photoelectric sunlight recorder is the ordinary solar radiation that is notoriously irregular and varying in intensity. Bright sunshine, which has a large beam element, is the most powerful radiation that creates the highest concentration and conversion potential. For example, a Photoelectric Sunshine Recorder measures the duration of bright sunshine at a local location. There are two selenium photovoltaic cells in the device, one of which is sheltered and the other is exposed to available solar radiation. Shading devices are additional devices used as environmental conditioners for diffusion measurement of radiation. The shading device blocks direct sunlight so that the sensor captures the reflected radiation from the surrounding objects. The signal output from both cells is comparable if there is no beam radiation, while the signal difference between the two cells is exploited in bright sunlight. Using this technique, bright hours of sunshine can be tracked. The Sunshine recorders were first developed by John Francis Campbell in 1853 and then modified by Sir George Gabriel Stokes in 1879. The original instrument was based on water-filled glass spheres and, later, solid glass spheres. This latter device known as the Campbell-Stokes (CS) recorder, is still being manufactured and used today and is the oldest solar radiation device in operation.

The solar radiation data composed by the abovementioned instrumental methods deliver the basis for any solar projects to be developed. The kinds of solar resource data can be summarized as shown in figure 5. Figure 6 shows the implementation of the abovementioned devices.
4. Result and Discussion

In general, as shown in Figure 7, the model consists of 4 parts. Several inputs are composed of the first part. A Pyranometer sensor, which integrates all the radiation parameters required, is the main input. Then, to get the real-time and precise time, a timer in the form of Real Time Controller RTC DCS1307 is used. In addition, GPS is implemented so that the precision of the device can be validated. Finally, to optimize the calculation of radiation parameters, there is a shading device.

The ESP32 NodeMCU microcontroller is the second part. It is the responsibility of the microcontroller to process incoming data, compute some calculation processes, and move the actuators according to a certain algorithm. Some motors and data logger is the third part. These engines work to move the system according to the angle of elevation, azimuth angle, and Sun position tracking. The calculated parameters thus obtain radiation that corresponds in real-time to the position of the Sun. The data logger feature stores the results of real-time data. A viewer of the processing results for all resulting parameters is the final part of this system. A Web-based viewer on a PC or smartphone displays the results of the calculations.

In Figure 8, the prototype of the proposed system is shown. Work on the sensor system is as follows. First, to get the Global Radiation \( (E_g) \) value, the Pyranometer works normally. After that, in phases at a certain angle, the shading device is driven by a servo motor. The motion of the shading device is carried out, while the Sun's radiation is blocked by it, to get the correct position. The position is that the system obtains the Radiation Diffusion value \( (E_d) \). The value of Direct Radiation \( (E) \) after getting the value of Global Radiation \( (E_g) \) and Diffuse Radiation \( (E_d) \) is obtained by calculation \((1)\). Finally, based on these three values, the radiation duration value is calculated by a certain algorithm using the time value from the Real-Time Controller. All the values are stored in a data logger and sent via internet transmission to the monitor station. Via a PC or smartphone, officers can get the value generated.
The system with only a Pyranometer sensor can produce data for the four radiation parameters needed, based on the work of the sensor system. Moreover, these values can be easily monitored in a remote.

5. Conclusions
The need for four solar radiation parameters, namely: Global Radiation, Direct Radiation, Diffuse Radiation, and the period of optimistic sunshine at a locale, has been explained in this paper. On the other hand, an effort needs to be made to efficiently simplify the measurement system for solar radiation parameters. A model of the sensor system is offered that can measure these parameters. The system’s job plan has also been well explained. Using a Pyranometer sensor with the aid of a shading device, a real-time controller, and a data logger can easily and efficiently measure all the required parameters. Using internet-based transmission makes it even simpler to monitor and record parameters of solar radiation more easily.

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