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Web based Measurement System for Solar Radiation

Shachi Awasthi[1], P. Mor[2]
Research Scholar (PhD) [1]
Scientific Officer, Rani Durgavati Vishvavidyalaya, Jabalpur[2]

Abstract

We present in this paper, the principles of the measurement system for solar radiation, and our implementation using Web based data logging concept. The photocurrent produced by Silicon PN junction is used as a solar radiation transducer, to make it more viable we have used commercially available solar panels as our transducers. Using a silicon solar cell as sensor, a low cost solar radiometer can be constructed. The photocurrent produced by solar cell is electronically tailored to be measured and stored by our web based data acquisition and monitoring system. Measurement using real solar cell array gives a good measure of actual producible energy by solar arrays. Our portable instrument can be used in remote sites and substitutes the solar monitor and integrator, Current data of solar radiation can be monitored using Ethernet interface available in all PC, Laptops. We store the data into a secure digital card which can be retrieved to plot and analyse the data.
We have developed system hardware and software based on ATmega32 AVR Microcontrollers and ENC28J60 Ethernet PHY and MAC network interface chip by Microchip. So the global irradiance data are obtained after correction using the instantaneous measurement of ambient temperature which allows us to calculate the junction temperature and consequently improve the precision of measurement of our data acquisition system.

Keywords

Solar Radiometer, Embedded Ethernet, Data Acquisition, Weather monitoring

1. Introduction

In recent years, introduction of alternative energy sources such as solar energy is expected. The solar heat energy utilization systems are rapidly gaining acceptance as some of the best solutions for the alternative energy sources. However, thermal energy collection of solar heat energy utilization system is influenced by solar radiation and weather conditions. In order to control the solar heat energy utilization system as accurate as possible, it requires method of solar radiation estimation.

In order to estimate the solar patters of a geographical location we must gather solar irradiance data over that site for some duration of time, based on that analysis we can predict the pattern of solar irradiance over that geographical location. That can help us to determine the viability of solar energy plants or implementation of solar projects in that area.

Many solar radiance meters are available in market, but most of them do not provide real time monitoring at remote site as well as logging of data over a long duration, they are too expensive also. We have tried to devise a new approach in which the real time solar radiance data can be monitored over Local area network or Web. We have included the reliable packet transmission model of TCP/IP as our real time data transportation model. We have proposed this low cost solar radiance measurement system using our embedded internet based Data acquisition system.

2. Conceptual background

The photo current induced by solar radiation in solar cell has been used as sensors in low cost pyranometers [1]. The spectral response of these sensors does not cover the full range of solar spectrum. The silicon has a high sensitivity to sunlight and it is possible to use it as pyranometer sensor.

In order to reduce the cost of this solar radiometer, we developed system hardware and software based around cheap ATmega32 microcontroller, ENC28J60 and some analogue circuits for preprocessing of signal from solar cells. Data can be transferred to PC over Ethernet, and can be stored at site itself. First option has the preference when working in remote sites with no qualified operators. The local measurement system gives instantaneous measured data and control the data acquisition operation.

3. Calibration of Sensors

1. Photovoltaic sensor

The photovoltaic (PV) sensors, based on silicon solar cell, produce a short circuit current directly proportional to the incident radiation. The spectral response of silicon solar cell is almost the same for different devices. Figure 1 shows the spectral response for AM1 [2] conditions and the silicon solar cell spectral [3].

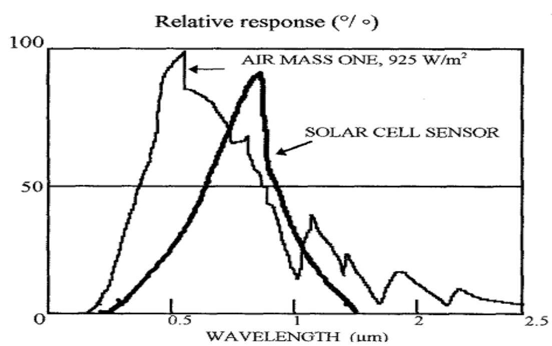

Fig. 1: Solar and sensor spectral response

The method of calibration is based on the measurement of the short circuit current produced by the PV sensor in function to solar energy irradiance measured, given by following relation[4]

Tj = Ta + [(NOCT-25)/1000] * E (1)

E, Tj and Ta represent respectively the solar radiation, the junction temperature and ambient air temperature.

The standard irradiation is equal to 1000 W/m^2 and the standard temperature is equal to 25° C. NOCT is the nominal operating cells temperature. Figure 2 shows the correlation between the short current – circuit produced by the PV cell and the solar radiation incident. The measurements have been made on different days and different atmospheric conditions.

The linear correlation coefficient is high, R=0.97 and the standard deviation is S_D = 3%

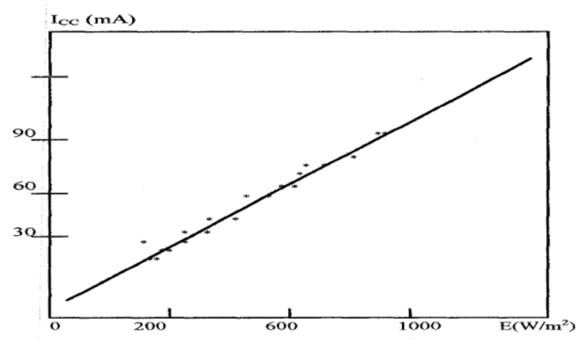

Fig 2: Calibration curve

The equation of calibration is given by:

$$\mathbf{I_{cc} = 0.843 * E + 0.039} \qquad (2)$$

However, junction temperature infects the short current- circuit produced by the PV sensor. So in order to have a best calibration, it is necessary to measure the short current-circuit at the same time as the ambient temperature.

Figure 3 shows the variation of short current –circuit (I_{cc}) in function of solar irradiation incident (E), in case of different temperature is always linear. The calibration curve is:

$$\mathbf{I_{cc} = K * E} \qquad (3)$$

K is the factor of calibration.

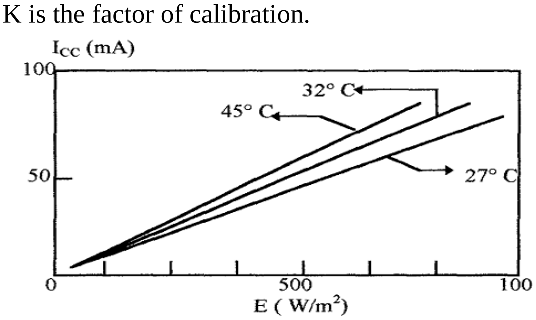

Fig.3: Sensor calibration curve

In this study, the mean factor K is equal to 80 mA / $KW.m^{-2}$. The standard error is 7% in the scale of temperature include between 27°C to 45°C.

In the other hand, in order to have the best precision of global irradiance measurement, we have calculated the calibration factor K_i corresponding to each temperature T_j.

$$\mathbf{I_{cc} = K_i * E} \qquad (4)$$

Knowing the factor K_i , suitable electronic circuit can convert the short current –circuit to voltage, amplify the signal and convert the solar radiation measurement into binary digits.

In order to have the correspondence between the voltage and solar radiation, the electronic circuit of this process is presented in Figure 4.

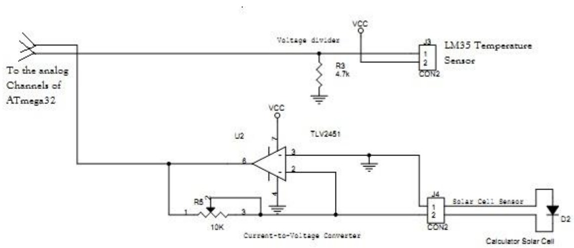

Fig. 4: Basic pre-processing circuitry

2. Temperature sensor

We have used a Temperature sensor module by national semiconductors, its part number is LM35, it is internally calibrated to output 10mV change in output voltage for every 1˚C rise or fall in temperature. LM35's low output impedance, linear output and precise inherent calibration make interfacing to read out or control circuitry especially easy. As it draws only 60uA from supply, its self-heating is very low almost around 0.1˚C in still air.

Data Acquisition System

Our data acquisition system for acquiring solar radiation is built around ATmega32 microcontroller and network interfacing is provided through an on-chip PHY and MAC layer solution by microchip in ENC28J60. This instrument of ours can be used for measuring many environment related parameter, this paper explains only solar radiance part.

Figure 5 shows the flow diagram of our solar radiation monitoring device.

We have designed a method of preliminary treatment of data at the site itself so that the remote monitor should get only the correct data and not all the garbage data coming. Our device allows storing the data on the site of device in a standard SD card, file from SD card can be transferred to PC easily and data can be plotted graphically to analyze the solar radiance data collected over a certain period of time

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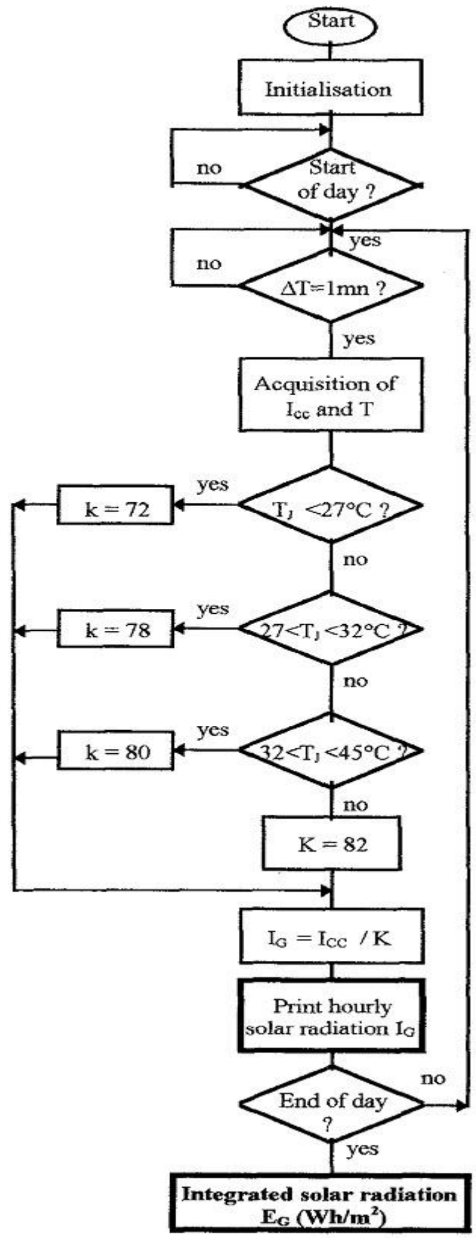

Fig. 5: Flow Chart of Solar radiometer System

Solar cells gives the photo current which is proportional to solar radiance, we first convert photocurrent to voltage using an Op-Amp based current to voltage converter, the result voltage from current to voltage converter is fed to the internal ADC of ATmega32. ATmega32 has got 8 channels of 10 bit SAC type analogue to digital converter. The digital data is then taken from ADC unit inside ATmega32 and packets are formed using this binary data, and these packets can be sent to the remote computer, when the remote computer requests for the same. Basically, our solar monitor device acts like a network HTTP server, which has a fixed IP address. Remote monitoring site acts like a HTTP client that can request data from a HTTP server. So remote site can use any standard web browser to see the real time data from the solar monitor device located at far end.

We have used an open source TCP/IP stack for AVRs and integrated it with our device to make it a fully capable network citizen. To store real time data at site we have included a SD card on our device that will store all the real time data and will store it into a file, which can be read by computer in continues interval and the data stored in file can be used to analyze the variation in solar radiance over a certain period of time.

4. Discussion and Results

The intensive use of modern day's electronics and microprocessor, microcontroller allows us to design a low cost and versatile radiometer. The data is acquired with an interval of 60s. Figure 6 shows the solar radiance received on a horizontal surface during a clear day with eventual clouds in the Jabalpur, Madhya Pradesh region of INDIA. Figure 7 shows the solar radiance of same region for a day but with a tilted surface.

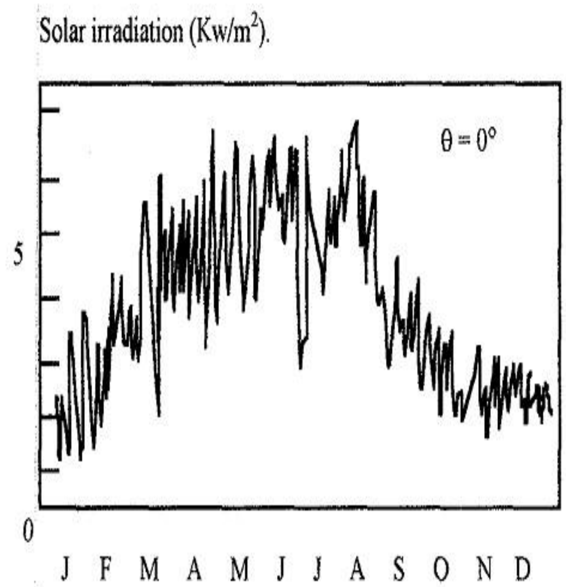

Fig. 6: Measured daily global radiation in Middle region of India in 2011

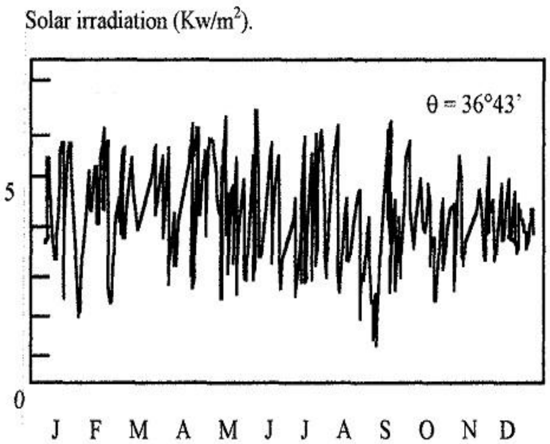

Fig. 7: Measured daily global radiation with tilted angle

5. Conclusion

In spite of insensitivity of silicon semiconductors for large wavelengths, the use of it as a sensor results in a good correlation with the actual solar radiation measured using an expensive pyranometer. Monitoring and processing solar radiation routines can be developed for any particular user interest. The semiconductor pyranometers coupled with automated data acquisition and logging system would greatly facilitate solar registers on remote sites on large scale and at low cost. The global irradiance data received on the tilted surface are obtained after correction using measurements of ambient temperature which allows to give the junction temperature and consequently to improve the precision of measurement. The automated data acquisition systems can be used to measure many metrological parameters and can be used for daily monitoring and logging of data to analyze the significant changes in regular patterns.

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Mrs. Shachi Awasthi Tiwari is pursuing her Doctorate at Rani Durgavati University, Jabalpur. She completed her Masters in communication systems in 2009 from Shri Ram Institute of Technology, Jabalpur.