Silicon Sensors for Systems for Assessment of Sun Potential

Irina P. Pavlova[1], Ilia I. Hadzhidimov[2] and Emilian B. Bekov[3]

***Abstract* – As a renewable source of energy, the Sun produces low-calorie energy. The transformation of the Sun energy into electricity can be done by photovoltaic modules. Their projection, construction and installation depend mainly on the available Sun potential. Consequently, the Sun radiation for every region is essential. The present article aims to outline and shows the features of the devices measuring Sun radiation. An accent is put on the silicon cells for systems for assessing the Sun potential.**

***Keywords* silicon radiation sensor, pyranometer.**

I. INTRODUCTION

The sunlight occurs to be a widespread source of energy in the contemporary way of living for improving the life comfort. A positive change in people's attitude towards using the Sun energy as a renewable source is observed. A proof for that is the introduction of the photovoltaic modules, transforming the Sun light directly into electricity. This energy depends on the equality of the Sun radiation, the climate, the presence of fogs, and the air pollution (presence of dust).

The following factors influence on the right construction of a photovoltaic sun system: location, relief and orientation in the definite terrain. The duration of the periods of the Sun shining and the great irradiation with sun rays make the Sun energy an economically grounded alternative. All of these factors are a condition for the easy and accessible service of the system. Hence, having reliable data of the available Sun potential is significant. It influences the planning and the best location of the PV modules directly. The right choice of the slope of the receiving surface leads to full utilization of the Sun energy, irrespectively of the location on Earth the observed region is in. The available Sun potential influences on the power of the foreseen and desirable PV system. The right assessment and the exact defining of the Sun potential have an impact on the costs of the projecting, the installing and the exploitation of the Sun installation. Therefore the high initial investment expenses are still the main reason for the slower entering and usage of the PV system by the mass consumer.

The intensity of solar radiation is needed in the design as well as in exploitation of equipment which uses solar energy.

[1]Irina P. Pavlova,Technical University in Varna, 9000, Bulgaria, E-mail: irinappavlova@yahoo.com

[2]Ilia Iv. Hadzhidimov, Technical University in Varna, 9000, Bulgaria, E-mail: i_hadzhidimov@tu-varna.bg

[3]Emilian B. Bekov, Technical University in Varna, 9000, Bulgaria.

The purpose of this article is to demonstrate that the expensive pyranometer with high level of accuracy can be successfully replaced by cheap silicon cells. They may measure the intensity of solar radiation with sufficient precision. A major problem in the use of silicon cells as solarimeter is the dependence between volt-ampere characteristic and temperature. The increase of temperature of the cell leads to efficiency decrease of silicon cells. This leads to strong nonlinear dependence of the intensity of solar radiation from the output voltage of the cell. Standard cells depending on their characteristics have a limit at which the voltage remains the same regardless the increase in the intensity of the sun. To avoid this, the cell's output voltage and the electricity are controlled by electronics. On the one hand this offsets the dependence on temperature and on the other hand, the output voltage decreases below the limit for the cell at maximum intensity of the Sun 1200 W/m^2.

II. EXPERIMENTAL DATA

Developed silicon cell type DIY, shown in Figure 1 has the following characteristics:

- Size 60x60x3 mm;
- Rated voltage 4,5 V;
- Short circuit current 50 mA;
- Waterproofing (polycarbonate).

Experiments to measure the solar radiation have been carried out with the developed silicon cell and a standard pyranometer Kipp & Zonen type CM 11 B, shown in Figure 2 with the following characteristics:

- Spectral range - 305-2800 nm;
- Sensitivity - 4-6 μV/W/m^2;
- Impedance (nominal) – 700-1500 Ω;
- Response time - 15 sec.;
- Non-linearly - $\prec \pm 0{,}6\%(\prec 1000 W/m^2)$;
- Temperature dependence of sensitivity - $\prec \pm 1\%(-10 to + 40^o C)$;
- Directional error - $\prec \pm 10 W/m^2$ $(beam 1000 W/m^2)$;
- Tilt error - None;

Fig.1. Silicon cell of the DIY type

Fig.2 Pyranometer Kipp & Zonen of the CM 11 B type[1]

- Zero-offset due to temp.changes $\prec \pm 2 W/m^2 at 5K/h$ temp.chenge;
- Operating temperature   - -40°C to + 80°C;
- ISO-9060 Class - Secondary Standard;
- Dimensions WxH- 150.0mmx91,5mm;
- Weight   - 850 grams [1].

For calculation of the solar irradiance the following formula has be applied:

$$E_{Solar} = \frac{U}{S} \qquad (1)$$

where

E_{Solar} – Global radiation , W/m^2;

U – Output voltage, μV;

S – Sensitivity, $\mu V / W / m^2$ [2].

The CM11 B pyranometer is intended for high accuracy total global, or diffuse sky, solar radiation measurement research on a plane/level surface.

Its usage is due to the following advantages:

- low dome thermal offset error;
- excellent cosine/directional response;
- excellent long term stability of sensitivity;
- excellent linearity performance.

The non-linearity error is shown on Figure 3.

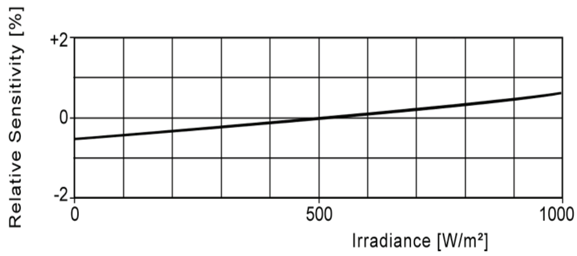

Fig.3. Non-linearity (sensitivity variation with irradiance) of Kipp & Zonen pyranometer CM 11 B.

The temperature dependence of the sensitivity is an individual function. For a CM 11 B the curve is somewhere in the shaded region of Fig. 4.

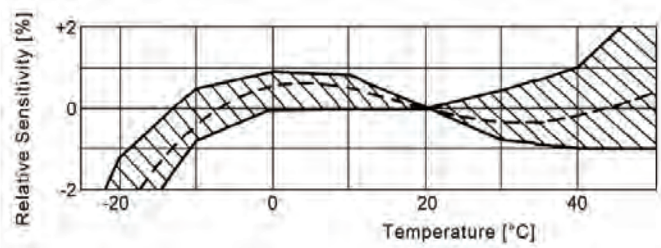

Fig. 4. The curve of relative sensitivity variation with instrument temperature of a pyranometer CM 11 B is in the shaded region. A typical curve is drawn [2].

The directional error is the summation of the azimuth and zenith error and is commonly given in W/m^2. Figure 5 shows the maximum relative zenith error in any azimuth direction for the CM 11 B.

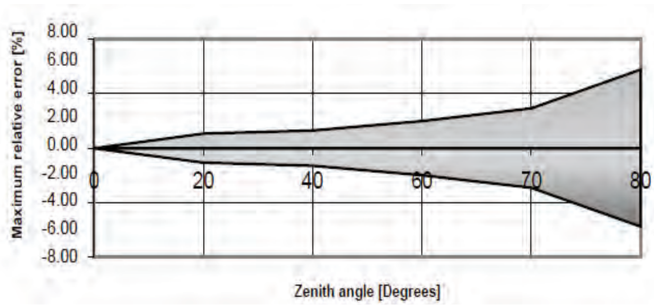

Fig. 5. Relative directional error [2]

Experiments to measure the solar radiation have been carried out with the developed silicon cell and a standard pyranometer Kipp & Zonen type CM 11 B. The experiments took place within the Technical University - Varna for a period of one month for 500 minutes per day. The time of memorizing the results from the experiment is one minute, which makes it possible to trace in detail the changes of the solar radiation intensity. Processing the results from the measurement of intensity of solar radiation with the developed silicon cell is performed with parabolic dependence:

$$E(x) = a.x + b.x^2 , \qquad (2)$$

where a = 6,55 b = -0,01 (for this cell) are regression equation coefficients.

For standard pyranometer CM 11 B the intensity of solar radiation is calculated as follows:

$$K\_Z(x) = \frac{x - 0,2}{0,8}.1600 \quad , W/m^2. \qquad (3)$$

The standard square deviation is calculated with formula (4), and the error of measurement between the readings of the two instruments is calculated with formula (5):

$$\sigma = \sqrt{\frac{\sum_{i=1}^{500} (\delta_i)^2}{500}} \qquad (4)$$

$$\delta = |K\_Z - E(Cell)|. \qquad (5)$$

Amongst the performed experiments, selected and displayed measurements are obtained during two sunny days (20.10. and 29.10.2008) and two cloudy days (24.10. end 21.10.2008).

The results are shown in Fig.6, Fig. 7, Fig. 8 end Fig.9.

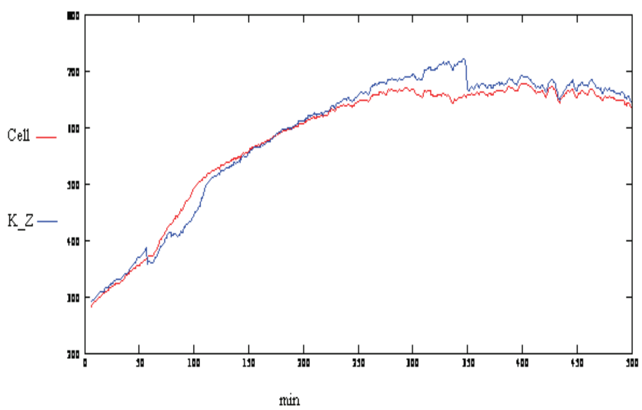

Fig. 6. Results of the intensity measuring of the Sun radiation on 20th October, 2008

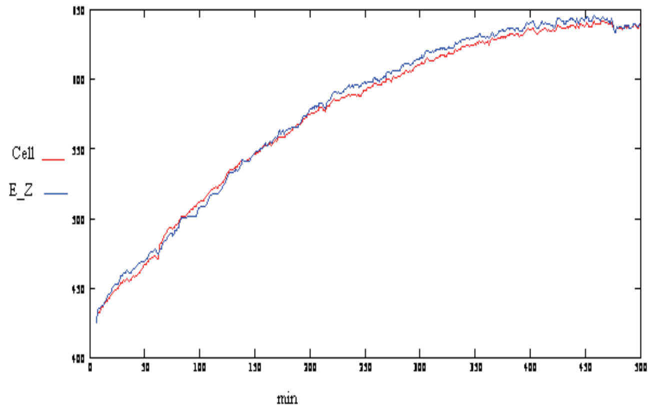

Fig. 7. Results of the intensity measuring of the Sun radiation on 29th October, 2008

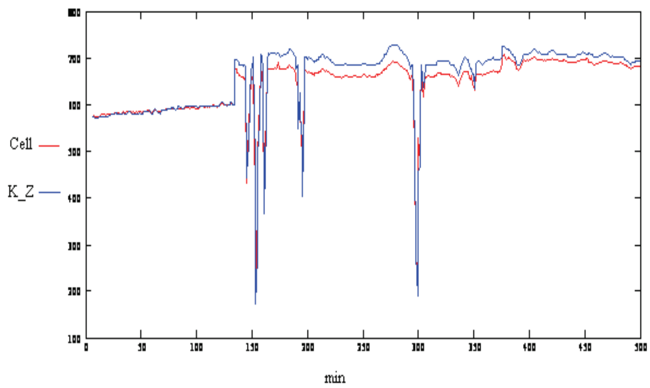

Fig. 8. Results of the intensity measuring of the Sun radiation on 24th October, 2008

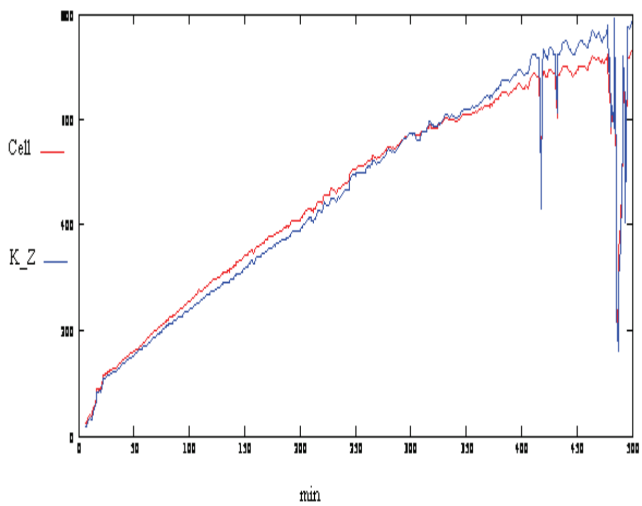

Fig. 9. Results of the intensity measuring of the Sun radiation on 21th October, 2008

Considering the results of measurements of intensity of the solar potential - the blue line (corresponding to the data of the standard pyranometer) and red line (solar silicon cell) show a good degree of matching. At two sites (Fig. 6) the deviations can be seen, caused by a shift in the position of the silicon sensor in azimuth in order to analyze the possible error by a change in the assembly position of the sensor. After the initial removal of the sensor, it is returned to starting position and the difference in readings with the standard was decreased. Figs. 8 end 9 compares the readings of the two solarimeters in a cloudy surrounding and a several peaks at high eclipse.

The error of measurement with silicon sell versus the standard pyranometer is shown on Fig.10, Fig.11, Fig.12 and Fig.13.

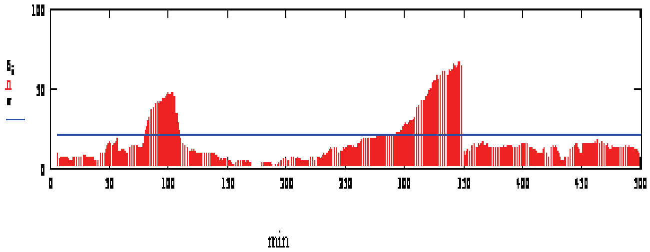

Fig. 10. Mistake of the measuring – 20th October 2008

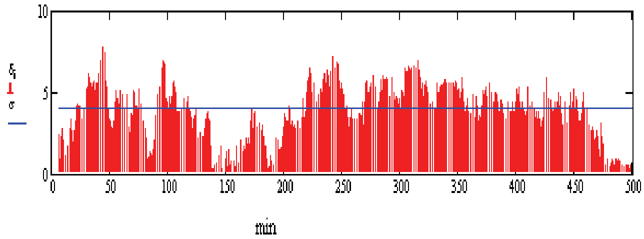

Fig.11. Mistake of the measuring – 29th October 2008

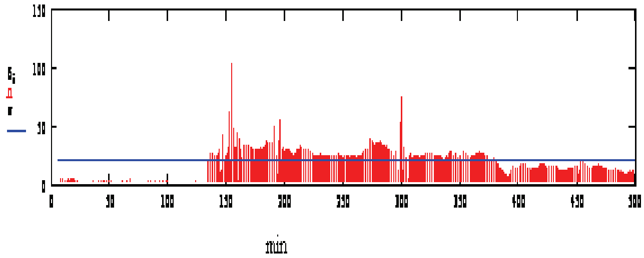

Fig. 12. Mistake of the measuring – 24th October 2008

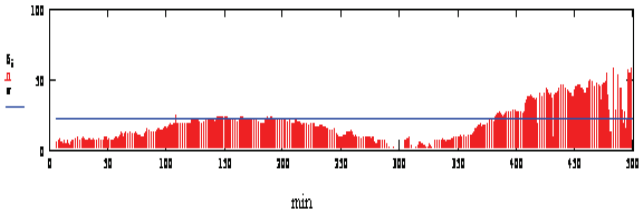

Fig. 13. Mistake of the measuring – 21th October 2008

According to formulas (3) and (4) and Fig.10, Fig.11, Fig.12 and Fig.13, the acentric square standard deviation and the maximum error obtained the following values:

$$\sigma = 21.34604\,; \quad \max(\delta) = 65.37476 W/m^2\,;$$

$$\sigma = 4.0774\,; \quad \max(\delta) = 7.6761 W/m^2\,;$$

$$\sigma = 21.56339\,; \quad \max(\delta) = 104.60971 W/m^2\,;$$

$$\sigma = 22.49228\,; \quad \max(\delta) = 58.92863 W/m^2\,.$$

III. Conclusion

The obtained data shows that the developed Sun sell can be successfully used for assessing the density of the Sun radiation. Such sensors are used even more frequently in the practice due to the following peculiarities:

- low cost;
- stability over atmospheric influences;
- compactness and simple geometrical form;
- chance for easy installment in different positions;
- acceptable accuracy in assessing of the Sun potential.

ACKNOWLEDGMENTS

The authors would like to extend their gratitude to Fund “Scientific Research” of the Bulgarian Ministry of Education for the support within Project “Development of specialized scientific infrastructure for investigation of wind and solar energy potential”, No.D 002-48/10.12.2008.

REFERENCES

[1] http://meteostanice.agrobiologie.cz/figs/cm11.pdf
[2]http://www.skypowerinternational.com/pdf/Radiation/7.14 15.01.000_cm11-14_bed-anleitung_engl.pdf