Assessment of Solar Irradiation to Estimating the Energy Production of Photovoltaic Panels Located in Craiova City, Romania

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Abstract: - The energy production of a photovoltaic system is mainly depending on the solar irradiation, (in W/m^2), available in the location where it is placed. Based on the solar radiation value, (in Wh/m^2) the photovoltaic system can be dimensioned, and estimates can be made of the generated electrical energy. This paper presents aspects regarding the evaluation of solar potential and energy production of photovoltaic systems in Craiova city, Romania.

Key-Words: - Solar irradiation, photovoltaic panels, photovoltaic system, solar energy

1 Introduction

Energy is currently a key issue for the global economy. World economic growth is threatened by the harsh reality of the depletion of world reserves of oil, natural gas, coal, nuclear fuel, and unreasonable exploitation of forests that are recovering at a slower rate than grazing.

One of the greatest challenges of the 21st century is to ensure that every citizen of the planet Earth has access to clean (non-polluting) energy, sustainable and at a reasonable cost [2].

In many places on Earth, the Sun has the ability to solve the need for energy that is becoming more and more acute with the increase of the world population and the raising of its standard of living, along with the exhaustion of conventional sources [2].

In order to investigate the possibilities of using the solar radiant energy (irradiation), it is useful to know the global radiation values received by the surface unit during a day, a month or a season in different geographic areas.

Of the meteorological factors, a particular influence on the solar radiation on the ground has: the transparency of the atmosphere, the nebulosity, the type of clouds, as well as their thickness and position [1]. This is how we can talk about (Fig. 1):

- Direct irradiation (G_D), is the radiation received from the Sun without being scattered by the atmosphere.
- Diffuse irradiation (G_{dif}), that occurs when the solar ray passing through the atmosphere is scattered, in other words, diffused in all directions.
- Albedo or reflected irradiation (G_R), is the radiation reflected from the surface of the earth and which falls on the solar panel.
- Total or global solar irradiation (G) is the sum of the three components falling on any surface.

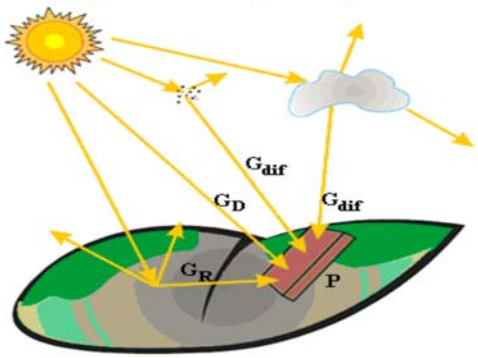

Fig. 1. Components of solar irradiation according to [1].

Usually, in the calculations and in the publications of the specialized institutes, the global radiation is considered.

In this paper we present the theoretical methods for the calculation of the solar irradiation available in Craiova city, Romania, completed with the real values obtained from the measurements.

2 Solar irradiation calculation

The simplified models of irradiation are empirical models resulting after fitting of a set of measurements, usually from a single location, which restricts their scope of applicability. This is an obvious disadvantage compared with the parametric models, which have a physical basis in spectral patterns, and the input parameters give them a generality trait. Still, the empirical models are commonly used in practice due to their simplicity. Further, we will be present some of these models, available under a clear sky.

In literature, one can find several models to determine solar irradiation, still in this study, some empirical models for estimating the solar irradiation specific to a certain location are particularized, as follows below.

- Adnot model, that models the global solar irradiation under conditions of a clear sky, by using the relationship [8]:

$$G_g = 951.39(\sin\alpha_s)^{1.15} \ [\text{W/m}^2] \qquad (1)$$

where:

α_s - is sun elevation angle

This pattern has been verified using the meteorological data of Romania collected from the meteo stations of the Romanian capital Bucharest, and the Romanian cities of Iasi, Craiova, Timisoara and Constanta. [8].

- Haurwitz model [8].

$$G_g = 1098 \cdot e^{\frac{0.057}{\sin\alpha_s}} \cdot \sin\alpha_s \ [\text{W/m}^2] \qquad (2)$$

- Kasten model [5]

$$G_g = 910 \cdot \sin\alpha_s - 30 \ [\text{W/m}^2] \qquad (3)$$

- Empirical model -EIM [10]

The empirical model elaborated by Paulescu and Schlett [10] had been assessed using the meteorological data recorded by the meteo station of Timişoara.

$$G_g = G_0\left[1 - 0.4645 \cdot e^{-0.69\sin\alpha_s}\right] e^{\frac{0.05211}{\sin\alpha_s}} \cdot \sin\alpha_s \ [\text{W/m}^2] \ (4)$$

All the empirical patters presented above need as inputs just the geographical coordinates of the location chosen and the temporal reference.

Applying the models presented as before for the location of Craiova City (latitude: φ = 44,23°, longitude λ = 23,87°) on the day of June 21 (as a day with high level of irradiation) and on the day of December 21 (as a day with low level of irradiation), respectively, the charts presents in Figures 2 and 3 have resulted.

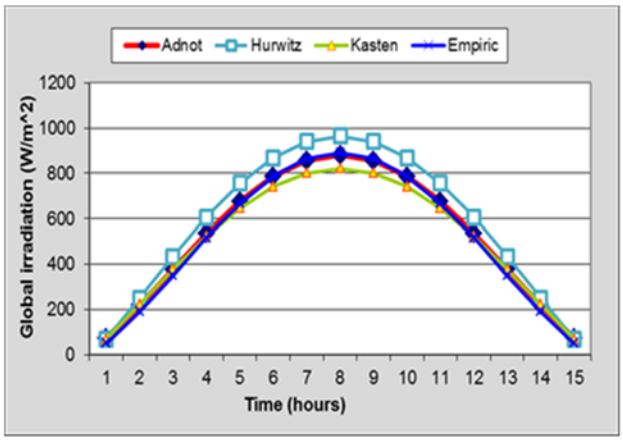

Fig. 2. Chart of global solar irradiation, in conditions of a clear sky, on June 21 for Craiova

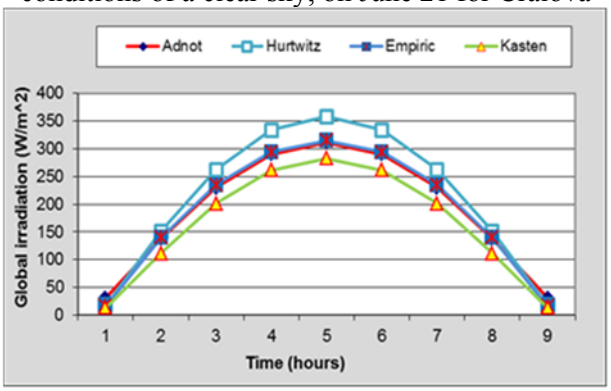

Fig. 3. Chart of global solar irradiation, in conditions of a clear sky, on Dec. 21 for Craiova

From the analysis of the charts of solar irradiation in conditions of clear sky for the location Craiova it results that the Adnot model and Empirical model are identical for both cases and represents an average of the charts corresponding to Haurwitz model and Kasten model.

Using dedicated software BlueSol was obtained monthly average of solar radiation based on NASA-SSE database (Fig. 4 and Fig. 5).

Craiova
Romania
Source of climatic data: NASA-SSE
Latitude: 44.31 °
Longitude: 23.8 °
Altitude: 105.0 m
T Max: 27.0 °C
T Min: -4.0 °C

Monthly average irradiance on horizontal plane

Month	Global [kWh/m²]	Diffuse [kWh/m²]
January	47.74	19.84
February	66.64	26.32
March	107.26	42.47
April	132.3	57
May	169.26	69.44
June	183	71.1
July	193.13	68.2
August	171.43	57.66
September	120.6	45.3
October	78.74	34.1
November	47.4	22.2
December	38.13	17.67
Year	112.97	44.28

Fig. 4. Monthly average irradiance of Craiova location

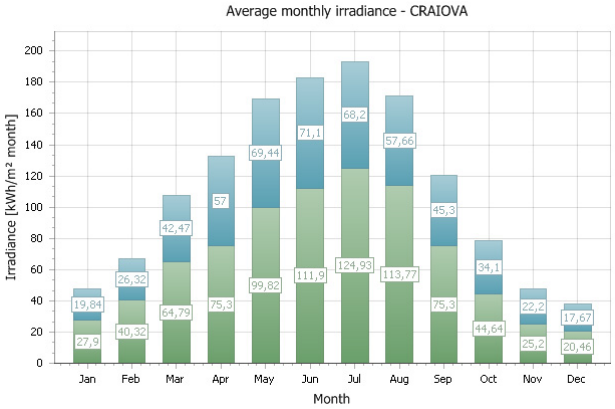

Fig. 5. Chart of monthly average irradiance of Craiova location

The graphs show that the annual average of global solar irradiation is 112.97 [kWh/m^2] and the monthly average is between 38.13 [kWh/m^2] and 193.13 [kWh/m^2].

3 Solar irradiation measured

Measurement of solar irradiation was carried out with the monitoring equipment of a photovoltaic system located in Craiova (Fig. 6 and Fig. 7).

Fig. 6. Equipment for measuring weather parameters: 1- pyranometer; 2- anemometer.

Fig. 7. Window of monitoring system

Weather parameters were monitored online and stored on an SD card.

Data is downloaded in * CSV format that can be easily imported into Excel and then processed in the desired form.

To analyze the correctness of calculated values of irradiation (Fig. 2 and Fig. 3) in Fig. 8 and Fig. 9 there are depicted the graphs resulting from the recordings made with the monitoring system.

Also, for a comparison of monthly average irradiation obtained with BlueSol software (Fig. 5), in Fig. 10 the chart of the average monthly solar radiation obtained from the measurements.

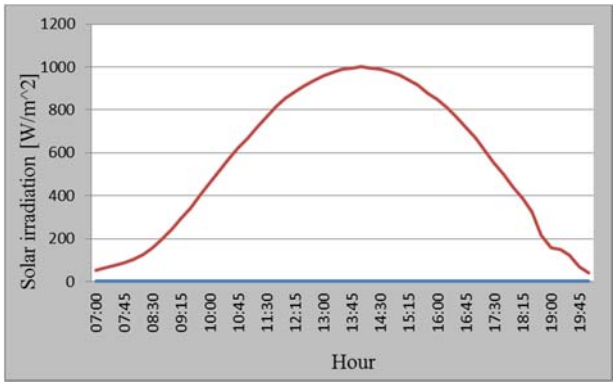

Fig. 8. Chart of global solar irradiation, measured on PV panel plane in 2016.06.21 for Craiova location

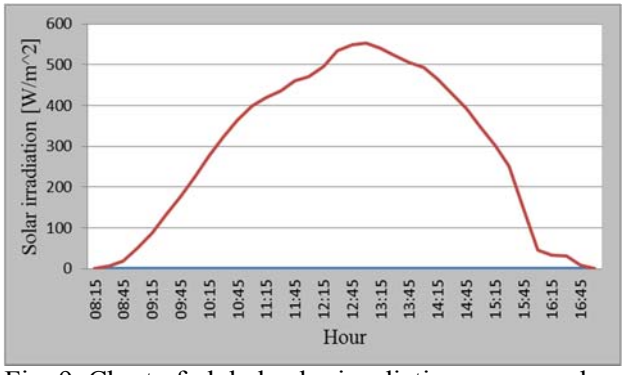

Fig. 9. Chart of global solar irradiation, measured on PV panel plane in 2016.12.21 for Craiova location

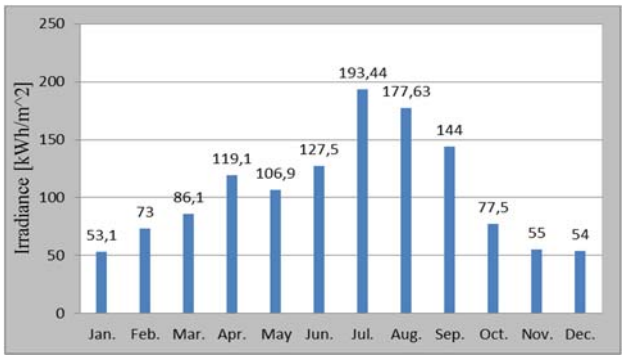

Fig. 10. Chart of monthly average irradiance measured on PV panel plane for Craiova location

As can be seen in Fig. 8 and Fig. 9 the measured solar irradiation values are higher than the calculated irradiation values because they were measured on the plane of the PV panels inclined at an angle of 30°. The calculated values were calculated for a horizontal plane.

4 Evaluate of energy production of a PV system located in Craiova

The photovoltaic system having a nominal power of 3 kW, located in Craiova and connected to the electrical distribution grid in Low voltage Single-phase alternating current a 230V have been experimented (Figure 11).

Fig. 11. PV system analyzed, located in Craiova

Using the BlueSol software, based on the available solar irradiation values at the Craiova location and the catalog data of the PV system equipment, the electric energy output of the analyzed system was estimated (Figure 12).

PV panels are made of Conergy 245 PJ polycrystalline silicon, with an efficiency of 15.4%. Also total system losses are about 14%.

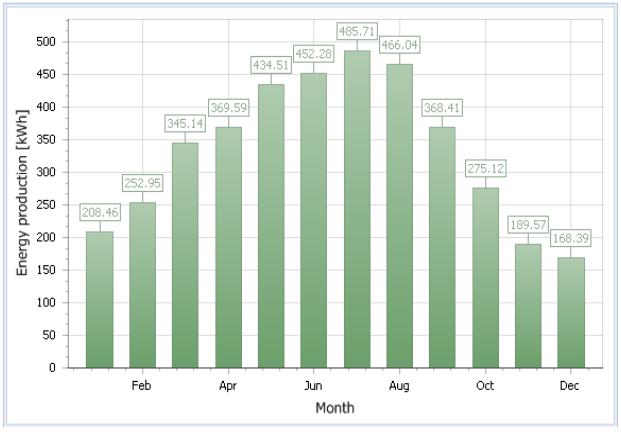

Fig. 12. Monthly energy production of PV system expected during the year

Summing up the monthly energy output results in an annual PV system energy output of about 4020 [kWh].

5 Conclusion

In this study was determined the solar irradiation by calculation and measurements, for a certain location. One could note that the measured values were close to the calculated values.

Also, the average annual radiation determined with the BlueSol software is 112.97 [kWh/m^2], and the one obtained by the measurements is 105,6 [kWh/m^2].

It must be highlighted that based on the information obtained on the solar irradiation available at that location, it is possible to estimate the energy output of the PV system.

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