RESEARCHES REGARDING THE EFFICIENCY OF PHOTOVOLTAIC PANELS

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Abstract: The article is structured in four parts. In the first part is given a general presentation about the renewable energies, the objectives of the European Commission until 2020, the importance of the solar energy. The second part presents some theoretical ideas that characterises a photovoltaic (PV) cell. In the third part are given the results obtained from some experimental measurements, as the last part describes the conclusions.

Keywords: solar energy, photovoltaic cell, efficiency, maximum power point

1. PRELIMINARIES

Regarding the green house gases reduction as well as the dependency of energy from the state are the objectives of the European Commission until 2020 are that 20% from the total requirements must be covered from renewable energy sources [5].

The Commission estimates that approximately 34% of electricity in the European Union will be result from renewable sources, which gives a growing from 16% in 2006, necessary to satisfy the global energy objective.

The development of European potential to use the renewable energies will have a contribution on the security of energy supply, will reduce the imports and the dependency on fuel, will reduce the emission of greenhouse gases, will increase the protection of the environment will be able to create new jobs and will enhance efforts towards a knowledge society [1,3,5].

The renewable energy sources, (RES), has a more and more importance in the European Electricity System. The solar energy has become a very important topic when the humanity has realized that the energy is a vital component for existence in conditions of modern civilization. The sun offers a possibility to resolve the energy crisis that has become increasingly pronounced due to the growing number of the population, its life standards growth, with exhaustion of the fossils and nuclear fission [1, 7].

In this article it was proposed to study the possibilities to increase the electric energy production with PV panels from sun.

It is known, that producers of PV panels have a large number of produce that may be categorised in many point of view. The panels may be classified in terms of their construction, i.e. what kind of cell is used for its construction, installed power, efficiency, the domain where they are used and many others.

Regarding the renewable energy resources Romania has a good potential. Also, it was collected a special experience of research – development activities in this domain. By many projects, can regain the confidence in the renewable technologies and there is checked their inexpensiveness. For this goal, concrete objectives of the research – development activities must give answer on the following basic objectives:

- Overcome the barriers to renewable energy development: costs, system and institutional efficiency;
- Alignment with EU rules and procedures of the field;
- Integration of renewable energy sources in national power systems.

2. CHARACTERISTICS OF SOLAR CELLS USED IN PRACTICE

For PV cell a great importance has the efficiency of the conversion [4, 6, 7]. It is the ratio of the generated electric power at the output and the power of irradiance:

$$\eta = \frac{I_m \cdot U_m}{P_{ir}} = \frac{FF \cdot I_{sc} \cdot U_{OC}}{P_{ir}} \quad (1)$$

where

FF – fill factor;
I_{sc} – short circuit current;
U_{OC} – open circuit voltage;
P_{ir} – power of irradiance

In fig.1, is given the voltage of open circuit and the short circuit current in function with the irradiance.

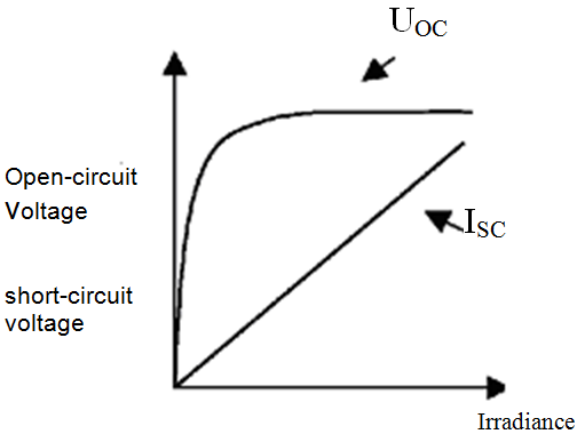

Fig.1. The voltage of open circuit and short circuit in function with the intensity of irradiance

Researchers of the National Renewable Energy Laboratory NREL from the USA attain a new record regarding the PV cell's conversion efficiency from light in electricity. So, they reached by the sunlight conversion in electricity an efficiency of 40.8% that is the greatest efficiency confirmed until now. For a PV cell the net current wil be given by (2):

$$I = I_s - I_d = I_s - I_0\left[\exp\left(\frac{U}{U_T}\right) - 1\right] \qquad (2)$$

where I_o is the intensity of saturation current with inverse polarization of the junction, as U_T is the thermal voltage, equivalent to the operating temperature of the junction defined by (3):

$$U_T = \frac{kT}{e} \qquad (3)$$

where:

k – Boltzman's constant;
T – the absolute temperature;
e – electron charge.

The power obtained may be calculated by relation given in (4):

$$P = U \cdot I = U\left\{I_S - I_0\left[\exp\left(U/U_T\right) - 1\right]\right\} \qquad (4)$$

The maximum value of this power is obtained in point M of the cell's I – U characteristic, the coordinates resulting from condition of $\delta P / \delta U = 0$ – are given by (5):

$$U_M = U_g - U_T \ln\left(1 + \frac{U_M}{U_T}\right) \qquad (5)$$

$$I_M = I_S\left(1 + \frac{I_0}{I_S}\right)\frac{U_M}{U_M - U_T}$$

When it is applied a passive load, the optimal value of the load resistance will be (6):

$$R_M = \frac{U_M}{I_M} \qquad (6)$$

This value is a variable one having a large domain in function with the level of irradiance. An important value for PV cells is the usage factor, defined by (7):

$$k_u = \frac{U_M I_M}{U_g I_S} \qquad (7)$$

But, the most important value for a PV is the efficiency of the conversion [4,6,7,9,10,11]. If there is obtained the maximum power point, PM, the efficiency of the conversion is (8):

$$\eta_M = \frac{P_M}{P_R} \qquad (8)$$

where

P_M – maximum power
P_R –irradiance power

3. EXPERIMENTAL RESEARCH OF SOME PV STRUCTURES PERFORMANCES

In the experimental research where made a number of measurements, to obtain values of the voltage that may characterize in terms of power a PV panel. The measurements where made with Fluke 345, being able to record the values [11]. The values that results from the made measurements are given in fig.2; in the graph are presented the values of the voltage in function with the time. It is noted that the value of the measured voltage decreases with the irradiance decrease, so, from 0.48 V at 22.20 h, decreases to 0.03 V, value that remains at this level till the following sunrise.

In fig.2 a, is given the value of the voltage for the period 12 – 18 h, where he voltage may have maxim, medium and minim values. In this period the maximum value is 2.4 V, the medium 2.38 V and the minimum 2 V.

Fig.2. The values of the voltage in function with the time

In fig.2 there are given the maximum, medium and minimum voltages, obtained from measurements made in different hours of the day.

The three values are given with different colours, with red is given the maximum voltage, with black de medium and with green the minimum voltage. For another measurement, when it was made in other period of the day, the measured values of the voltages has values between 2.5 and 0 V. The maximum value exceeds 2.6 V as in the following moment it decreases to 2.1 V.

The distribution of the minimum voltage values are given in fig. 3.

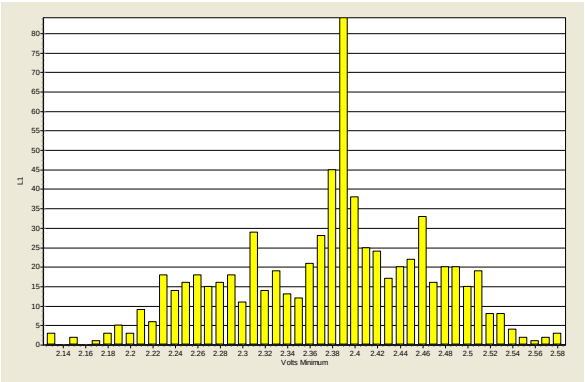

Fig.3. Distribution of the minimum voltage values

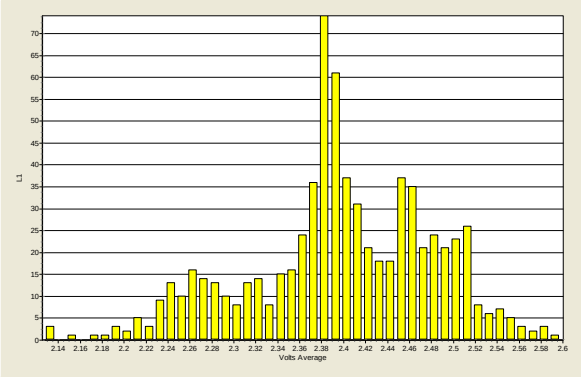

Fig.4. Distribution of the medium voltage values

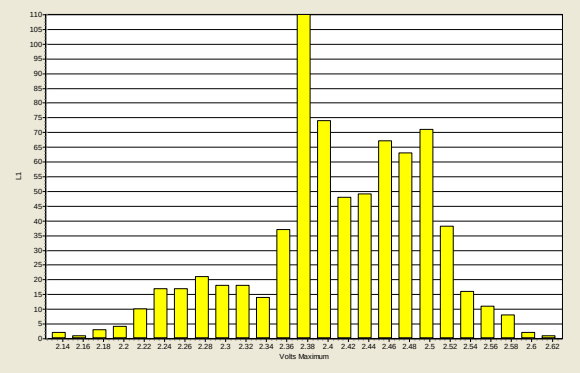

Fig.5. Distribution of the maximum voltage values

The voltages given in the above three graphs, have a discrete uniform distribution of triangle form. The most probable distribution for this period of study is approximately 95% when the obtained voltage is 2.53 V, and 5% for 2.25 V.

Another set of measurements where made with a PB panel model Solara SM 200S having the following characteristics:

- Produced energy or a summer day: 220 Wh / d;
- Maximum produced energy 55 W;
- Voltage 12 V;
- Voltage at maximum power point: 17,6 V;
- Short circuit current: 3,4 A;
- Number of cell on panel: 36 pieces;

It was realized a scheme, with this scheme were made the measurements; in this case were measured the voltage, current, temperature and the irradiance intensity on the surface of the solar panel.

The used circuit in its component has a solar panel, an electric consumer of 40 W, a device to measure the current and another device to measure the voltage. The consumer is series connected with the device Metrix important to measure the continuous current, as in parallel is connected the device Fluke to measure the continuous voltage, produced when the sunlight incidence on the collector of PV. In the first phase of the measurements these were made in the afternoon after 18.00 hour, in 10 in 10 minutes, the panel having a position toward S-W with inclination 60^{o}.

The measured values are the temperature on the surface of the panel, the voltage, irradiance, produced current and the intensity of the light. With the obtained values by measurements, it was possible to calculate the power for the respective moment.

In table 1 there are given the measured values, obtained with the above conditions.

Table 1. Values of measurements and the values of calculated values

No.	Hour [h,min]	t [°C]	U [V]	I [A]	Light intensity [lux]	P [W]
1	18.40	32	0.195	1.8207	72900	0.3657
2	18.50	32	0.178	1.8938	73600	0.3245
3	19.00	32	0.172	1.713	72500	0.2946
4	19.10	31	0.160	1.6048	69900	0.2567
5	19.20	30	0.153	1.5623	64800	0.23903
6	19.30	28	0.209	0.20339	57100	0.04256
7	19.40	28.5	0.166	0.35229	51500	0.0584
8	19.50	29	0.213	0.08761	51300	0.3991
9	20.00	28	0.263	0.16421	45800	0.431
10	20.10	26.5	0.262	0.14631	21800	0.383
11	20.20	26	0.134	0.30928	4480	0.0414

In fig. 6 is given the variation of the voltages for different time of the day.

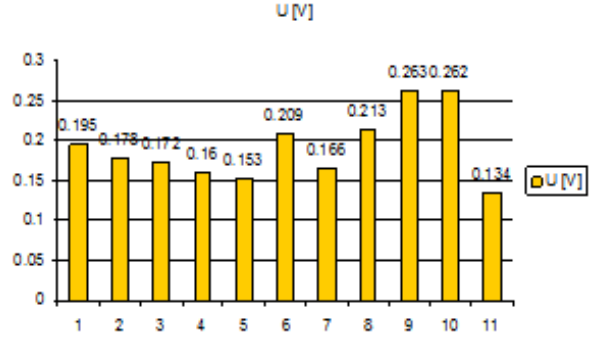

Fig.6. Distribution of the voltages

In this case, the values are given for a period of 2 hours; from the obtained graph results the same distribution with the distribution given in fig. 5. In fig.7 is given the values of the voltages and currents also for the same period.

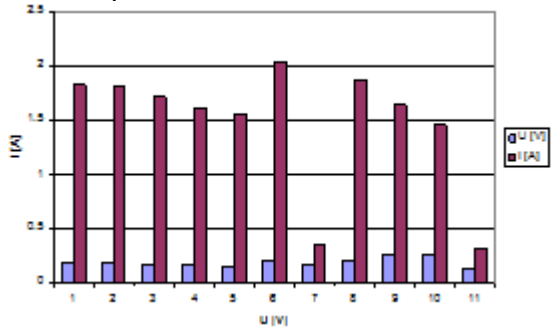

Fig.7. The voltages and he currents

It is noted that, to small values of the voltage belongs higher values of current. In the following graph is given the obtained power in function with the measured currents and voltages, fig. 8.

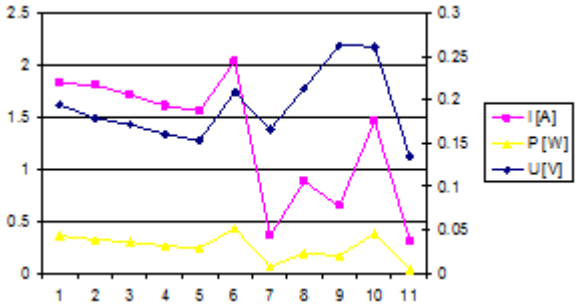

Fig.8. Variation of the power, voltage and current for the analysed period

The maximum value of the power is 0.3657 W when the current and the voltage have value of 0.195 V respectively 1.8207 A.

The effect of the solar intensity on the electric power production is given in fig.9.

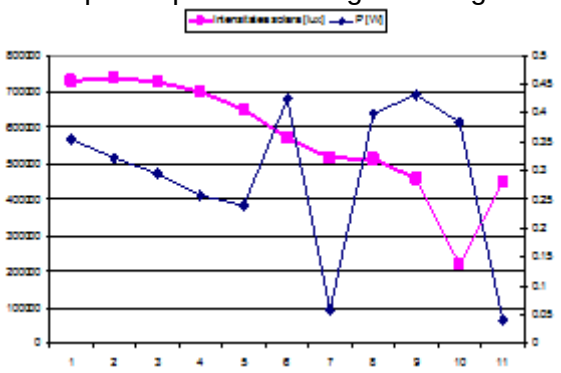

Fig.9. The power in function with the solar intensity.

It can be seen that in such operation conditions the PV panel produces 1.5659 W in one hour.

In the followings will be presented results obtained from another set of measurements, made in the same conditions as in the above case, the difference is that the panel of PV has an inclination of 30^o.

The measurements were made when the meteorological conditions were the same as in the above example. These were made for 3 hours in 5 in minutes.

In fig. 11 is given the obtained power in relation with the light intensity after the conversion of the solar radiation.

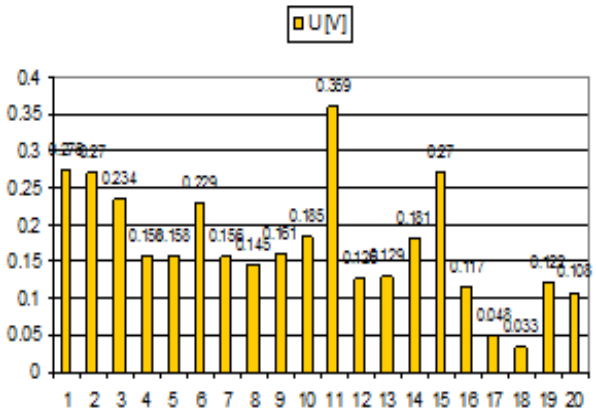

Fig.10. The voltage variation in function of the time

The maximum values of the power in this case is 0.60533 W, obtained with a voltage of 0,275 V and a current of 2.2012 A. The power produced in one hour is 2.5 W / h.

Another set of measurements also were made, but the panel had an inclination of 30^o and 60^o.

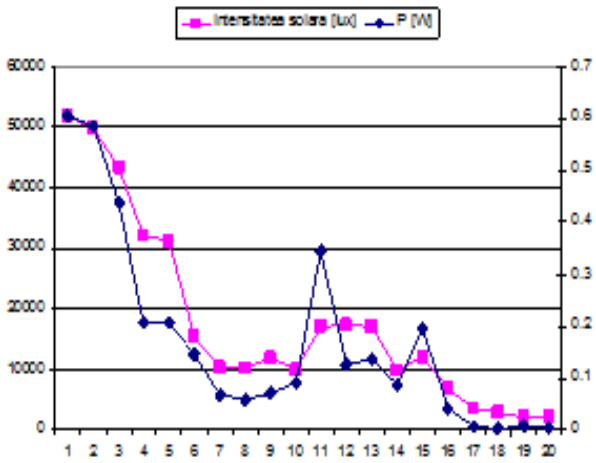

Fig.11. The power and solar intensity

For the following case the measurements were made with a panel tilted on 45^o. In the fig.12 is given the value of the voltages measured in period of 11.00 – 13.30.

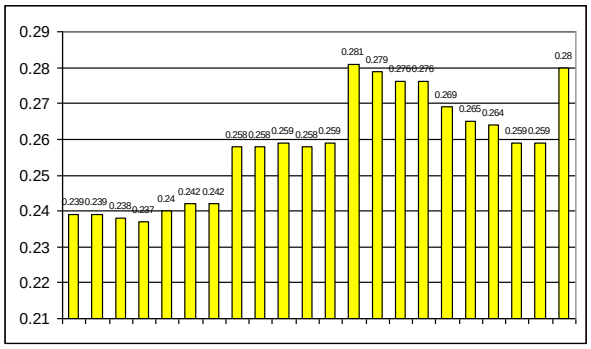

Fig.12. The values of the voltage with a tilt of 45^o

In fig.13 are given the values of the voltages measured with a panel having a tilt of 30^o.

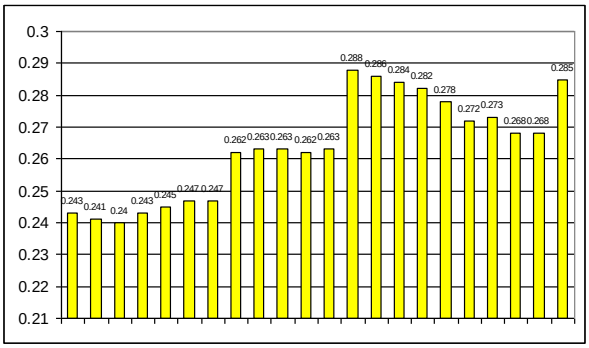

Fig.13. The values of the voltage with a tilt of 30^o

It can be seen that in the same condition of radiation is obtained a higher voltage with a panel tilted on 30o as with a panel tilted on 45o.

4. CONCLUSIONS

The strategy of energy of Romania for period 2007 – 2020, as objective proposes that energies obtained from renewable sources must represent 33% of the consume in 2010, 35 % in 2015 and 38 % in 2020.

From the above results that the renewable energy's study is important regarding to obtain new energy sources to produce electricity and thermal energy too.

The state of the art in this field is characterized by:

- The reliability of the systems have a high level;

- The design and system modelling were improved well;
- Regarding the batteries from this type of system, having the role to stock the obtained energy is yet unsatisfactory;

These systems are differing from independent systems because the electric energy is partial stocked for proper services; this energy is consumed by the consumer, as the excess of energy is injected to the power system.

The solar energy has many advantages:

- It is a renewable source, free;
- It has different field of application;
- Doesn't have pollution characteristic on to the environment;

The systems with this energy source have a relative great operating period, above 25 years; the panels of photovoltaic are guarantied for 20 years. The maintenance costs are low, doesn't require permanent supervision.

Installation costs are lower for stand alone zones as for those with connection to the national system. The installation of this kind of systems can be made quickly, without a great number of equipment and staff.

The measurements were made for location Oradea, having the following geographical situation:

- Latitude: 47.1^{o} on North
- Longitude: 21.9^{o} on East
- Elevation: 140 m

As a conclusion, from all above treated, can be saying the followings:

- The intensity of the light depends on the hours of the day;
- The light intensity doesn't depend in the temperature;
- The obtained current and voltage depends the light intensity;
- The obtained values of the power depends also from the wind speed, as, if doesn't exist wind it is obtained a higher value for the power, as for cases when exist wind even at load speed;
- In terms of geographical position, for Oradea's condition can say that a higher power is obtained if the PV panel is positioned with 30^{o} inclination, with 4 – 5 % greater as for case when the panel has a tilt of 45^{o}.

Referring on the produced voltage by he PV panel, used for experimental testing may be affirmed the followings:

- The values of the voltage follows the level of the irradiance;
- The minimal voltage has a normal distribution and it is between (2.14 – 2.18)V
- The medium voltage has also a normal distribution between (2.14 – 2.6) V
- The maximum voltage has values between (2.14 – 2.62) V.

From experimental model of a PV with the presented, results that for case with constant radiation, the obtained maximum power is the expected value.

REFERENCES

[1] F. ADAMO, F. ATTIVISSIMO, A. DI NISIO, A. M. L. LANZOLLA, M. SPADAVECCHIA, Parameters Estimation for a Model of Photovoltaic Panels, XIX IMEKO

[2] World Congress Fundamental and Applied Metrology Lisbon, Portugal, September 6-11, 2009

[3] ALNATHEER O. The potential contribution of renewable energy to electricity supply in Saudi Arabia, Energy Policy 33 (18) pp. 2298 – 2312, 2005

[4] ASHRAE, Handbook of HVAC Applications. ASHRAE, Atlanta, 2007

[5] BARLA E., G. BADEA, *Predictions on PV Technology Development In the Light of Kyoto Protocol*, The 5th International World Energy System Conference, Mai, 2004

[6] GOETZBERGER A, HEBLING C, SCHOCK H-W, Materials Science and Engineering 40 p. 1–46, 2003

[7] GOETZBERGER A. V.U. HOFFMANN, *Photovoltaic Solar Energy Generation*, Springer Series in Optical Sciences, 2005

[8] KALOGIROU S., Solar Energy Engineering: processes and systems, Permissions may be sought directly from Elsevier's Science & Technology Rights Department in Oxford, UK, 2009

[9] MAH El SAYED, Solar supported steam production for power generation in Egypt, Energy Policy 22 (10), pp. 1251 – 1259, 2005

[10] MARKVART T., L. CASTANER, Technical Handbook of Photovoltaics, Fundamentals and Applications, Elsevier, Ltd, 2003

[11] Photon das Solar Magazine, nr.1, 2009

[12] REINDL D. T., W. A. BECKMAN AND J. A. DUFFIE *Evaluation of hourly tilted surface radiation models*. Solar Energy 45 (1), 9–17. Solar Spectra, 2007