PARAMETERS ANALYSIS OF THE PHOTOVOLTAIC SYSTEMS TO THE VARIATION OF THE INCLINATION ANGLE TO HORIZONTAL PLANE

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ABSTRACT: This paper deals with a major technical problem, namely the use of solar energy to produce thermal energy. In this since has been studied the behaviour of a photovoltaic systems, being analysed the behaviour of the system depending on the angle of inclination varying between 30, 45 and 60 degrees relative to a horizontal plane.
KEY WORDS: Energy conversion, solar heating, renewable energy sources, photovoltaic variables measurement.

1. INTRODUCTION

Increasing the efficiency of photovoltaic systems in terms of electricity production is obtained by increasing the number of units installed with the disadvantage that both project expenditures increase with the use of multiple solar panels and also the space used by these panels.

In remote areas inhabited, placed at long distance from the public system of electricity distribution, the option of coupling to the mains electricity can be done, but involves considerable costs. In these circumstances an attractive and inexpensive solution is represented by the use of the photovoltaic systems.

For the moment, the use of photovoltaic systems in such locations may be preferred due to the reduced impact on the environment, correlated with the performance increase of storage batteries (rechargeable) or to promote renewable electricity supply services for the isolated systems used in information and communications (radio, TV, phone). Minimal energy demand for the domestic lighting, or other low electricity request for different services such as refrigeration, can also be satisfied by such photovoltaic systems.

The production of electricity by using photovoltaic panels is appropriate in the current context of Romania [1], [2]. According to the legal framework that supports renewable energy, the payback period is between 5-14 years. In this sense is necessary to support the electricity production by using photovoltaic panels based in Romania, which the European level is about 2-3 euros / W p.

In this paper were debated the fixed PV systems, tilt at 30^o, 45^o and 60^o towards the horizontal plane.

2. SIMULATION OF FUNCTIONING PHOTOVOLTAIC PANELS DEPENDING ON THE ANGLE OF INCLINATION

Simulation of operating conditions of the system, in order to determine the operating parameters of photovoltaic panel depending on the angle of inclination thereof relative to the horizontal plane was made using RETScreen software package [6].

In this sense was performed a number of 10 simulations where were are considered fixed photovoltaic panels, by using RETScreen - SFV software package.

2.1 Simulation with RETScreen of SFV fixed panel

In order to obtain a sufficient amount of electricity which can then be used, in the systems with fixed photovoltaic panels these can be set to an angle to the horizontal namely 30° / 45° / 60°; in the amount of electricity might be used for the lighting of streets, or to supply energy for different facilities in the city or in remote locations.

In the first stage of the analysis has been chosen the type of project, namely the production of electricity, and is the photovoltaic technology applied to an isolated network [3].

In the next step, was chosen the geographic locality Oradea, characterized by geographic coordinates where can be determined the meteorological data which have a great importance on the results of the use of photovoltaic panels (Table 1) [4].

In order to perform the simulation has been used RETScreen software, with which we achieved several types of simulations that are divided into several situations.

Table 1. Data representation of geographical and weather for Oradea

	Unit	Place of meteorological data	Project location
Latitude	°N	47,1	47,1
Longitude	°E	21,9	21,9
Altitude	M	140	140
Temperature calculation for heating	°C	-10,8	
Temperature calculation for cooling	°C	30,6	
Amplitude of the soil temperature	°C	21,2	
Relative humidity	%	78,8	

The variables used in the program are analysed by time, days, months and years:

- ambient temperature [°C];
- relative humidity [%];
- daily solar radiation [kWh/m^2/zi];
- atmospheric pressure [kPa];
- wind speed [m/s];
- soil temperature [°C];
- degree-days for heating [°C-z];
- degree-days for cooling [°C-z].

2.2 The Energy Model - electricity production project

For the analysis of PV, we used the existing database into the software RETScreen, by choosing photovoltaic cell with the following characteristics (Table 2).

Table 2. Photovoltaic panel features

PV cell type	**Mono silicon**
Manufacturer	BP Solar
Type	Mono silicon BP 1210
Power	10 W
T_n	45°C
Efficiency	7,8 %
Inclination angle	45°
Surface area	0,13 m^2

In Figure 1, are presented the windows used in system design. Was chose a system consisting of 5 units, photovoltaic panel with an efficiency of 7,8%.

In the considered photovoltaic system, the panel is fixed with position 45°. The obtained values for annual solar radiation for horizontal position is 1,25 MWh/m^2, and in the case of 45° sunlight inclination 1,42 MWh/m^2. By inserting the value of $ 240 / MWh for electricity price exported. The electricity network has delivered the value of 0,047 MWh a year. The cost analysis is presented in Figure 2.

In this case, the cost analysis is studying the feasibility of project development during system operation, electricity generation system comprising photovoltaic panels, access roads, power lines, transformer station, and electrical efficiency measures. Initial costs include annual costs, operation and maintenance as well as user-defined periodic costs.

Month	Annual solar radiation - horizontally - kWh/m²/zi	Annual solar radiation - 45°tilt - kWh/m²/zi	Price of electricity exported $/MWh	Electricity delivered to the grid MWh
January	1.25	2.36	240.0	0.003
Febraury	2.12	3.40	240.0	0.003
March	3.17	4.03	240.0	0.004
April	4.37	4.64	240.0	0.005
May	5.35	5.02	240.0	0.005
June	5.67	5.04	240.0	0.005
July	5.66	5.16	240.0	0.005
August	5.05	5.10	240.0	0.005
September	3.69	4.37	240.0	0.004
October	2.35	3.45	240.0	0.004
November	1.33	2.35	240.0	0.002
December	0.98	1.88	240.0	0.002
Yearly	**3.42**	**3.90**	**240.00**	**0.047**

Annual solar radiation	- horizontally	1.25	MWh/m²
Annual solar radiation	- 45° tilt	1.42	MWh/m²

Photovoltaic		
Type		mono-Si
Installed power	kW	0.05
Manufacturer		BP Solar
Model	5 unit(s)	mono-Si - BP 1210
Efficiency	%	7.8%
Nominal Operating Cell Temperature	°C	45
Temperature coefficient	% / °C	0.40%
Solar collector area	m²	1
Various losses	%	5.0%
Inverter		
Efficiency	%	96.0%
Capacity	kW	7.0
Various losses	%	25.0%
Summary		
Utilization factor	%	10.8%
Electricity delivered to the grid	MWh	0.047

Figure 1. Interface of the RETScreen energetic model used for the production of electricity through photovoltaic panels

RETScreen cost analysis - Electric Power Production Project

Setings

Method 1
Method 2

Notes/Field | Define by user | Define by user

Initial cost (loans)	Units	Quantity	Unit cost	Amount	Relative cost	Notes/Domain
Feasibility study						
Feasibility study	cost	1	$ 350	$ 350		
Sub total:				$ **350**	2.3%	
Development						
Development	cost	2	$ 130	$ 260		
Sub total:				$ **260**	1.7%	
Engineering						
Engineering	cost	1	$ 1,000	$ 1,000		
Sub total:				$ **1,000**	6.6%	
Electric energy production system						
Photovoltaic	kW	0.05	$ 4,850	$ 243		1Wp = 4,84 $
Access routes	km	15	$ 75	$ 1,125		
Electrical lines	km	30	$ 75	$ 2,250		
Transformer station	proiect	1	$ 75	$ 75		
Measures of energy efficiency	proiect	1	$ 65	$ 65		
Defined by user	cost	1	$ 150	$ 150		
				$ -		
Sub total:				$ **3,908**	25.8%	
System maintenance and miscellaneous						
Spare parts	%	20.0%	$ 250	$ 50		
Transport	proiect	1	$ 2,000	$ 2,000		
Initiation	p-z	1	$ 2,000	$ 2,000		
Defined by user	cost			$ -		
Unexpected	%	20.0%	$ 9,568	$ 1,914		
Interest rate during construction	19.00%	40 lună(i)	$ 11,481	$ 3,636		
Sub total:				$ **9,599**	63.5%	
Total initial costs				$ **15,117**	100.0%	

Annual costs (loans)	Unit	Quantity	Unit cost	Amount	Notes/Domain
Operation & maintenance					
Workforce parts	proiect	5	$ 50	$ 250	
Defined by user	cost			$ -	
Unexpected	%	5.0%	$ 250	$ 13	
Sub total:				$ **263**	

Period costs (loans)	Unit	Year	Unit cost	Amount	Notes/Domain
Defined by user	cost			$ -	
				$ -	
Project residual value	cost			$ -	

Figure 2. Cost analysis for the considered case

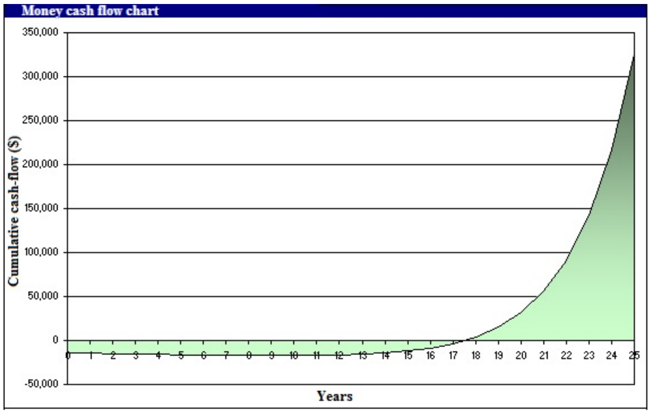

Figure 3. Financial analysis

Figure 3 presents the financial analysis of the project (calculations were carried out in dollars), where were calculated the values of financial parameters, project costs and savings generated, financial viability, cash-flow chart currency.

Total initial costs are $ 15.117, including annual costs and loan rates are $ 380, the cost - benefit is 2.63, which means that this system is profitable. Financial analysis of that plant will be profitable after 17 years, reaching in the 25th year to the amount of $ 325.270 profit.

Table 3 shows the values of the electricity supplied to the network, obtained through simulations.

Table 3. Energy values supplied for 30º, 45º, 60º

No.	Installed power [kW]	No. of units [pc]	Supplied energy [MWh]		
			30º	45º	60º
1	0,05	5	0,048	0,047	0,045
2	0,10	10	0,095	0,095	0,090
3	0,15	15	0,143	0,142	0,135
4	0,17	17	0,162	0,161	0,153
5	0,20	20	0,191	0,190	0,181
6	0,25	25	0,238	0,237	0,226
7	0,30	30	0,286	0,285	0,271
8	0,35	35	0,334	0,332	0,316
9	0,40	40	0,381	0,380	0,361
10	0,45	45	0,429	0,427	0,406

Simulations for the considered PV system with fixed positioning and angles at 30º, 45º and 60º were conducted under the same conditions with the same number and type of panels.

If simulations were performed at 30°, the amount of energy delivered is 0,429 MWh / year, for a number of 45 panels each panel having the 50 W power installed.

If simulations were performed at 45°, the amount of energy delivered is 0,406 MWh / year, for a number of 45 panels each panel having the 50 W power installed.

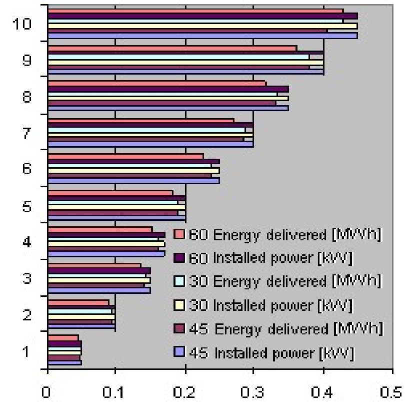

Figure 4. Representation of the three types of simulations for inclinations considered

If simulations were performed at 60°, the amount of energy delivered is 0,427 MWh / year, for a number of 45 panels each panel having the 50 W power installed.

From this comparison of the values resulting from simulation may conclude that although differences in power delivered for different inclinations of photovoltaic panels are small, however in the long term operation these differences are considerable and can easily see which is the best angle of operation and exploitation of the PV system.

From the point of view of obtaining electric energy the follows from the foregoing that in the case with fixed positioning system, the most efficient position is that of the unit at 30°.

Figure 4 presents graphically the values obtained for the energy delivered in function of the installed power, which according to the values in Table 3 for option 1 where we have 5 photovoltaic panels mono silicon BP 1210, after which for the following positions are added each 5 panels reaching in final to the number of 45 panel (position 10 in table 3).

3. EXPERIMENTAL RESULT FOR DIFFERENT TILT ANGLE OF THE PV PANEL

The experimental measurements were performed by using the interactive laboratory module LabSoft Lucas-Null's [7], in order to measure the value of daily solar radiation (Figure 5). Solar module makes it possible to investigate a variety of irradiation scenarios. With the help of a software tool, it is possible to set the solar elevation angle as a function of latitude, date and time of day. The experimental module allow us to vary the position and light intensity of the sun using a halogen lamp that can be oriented so as to simulate the position of the sun during the day with its light intensity value of the radiation. As in the case of the simulation results with RETScreen program, in the experimental conditions were kept the photovoltaic panel angles to 30°, 45° and 60°.

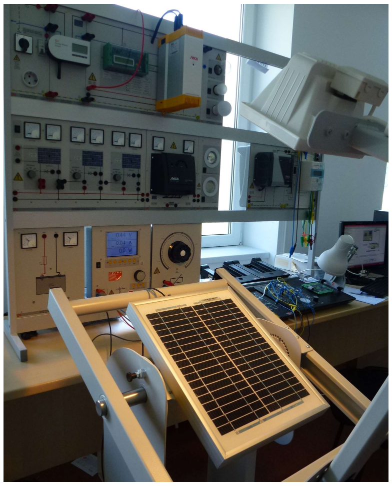

Figure 5. Training panel solar module simulation

The results shown in Table 4 and Figure 6 were obtained without a consumer (electrical load - idle).

Table 4. Without load

No.	Sun incidence angle [°]	Time of the sun in the sky	Luminous intensity [W/m²]	Voltage on the panel [V]		
				30°	45°	60°
1	60	5	100	15,27	15,40	14,30
2	45	7	170	17,67	17,69	17,31
3	30	9	240	19,01	18,89	18,80
4	15	11	310	19,64	19,64	19,41
5	0	13	380	**19,85**	**19,87**	**19,65**
6	-15	15	310	19,59	19,60	19,34
7	-30	17	240	18,91	18,95	18,69
8	-45	19	170	17,70	17,72	17,45
9	-60	21	100	15,17	15,17	15,18

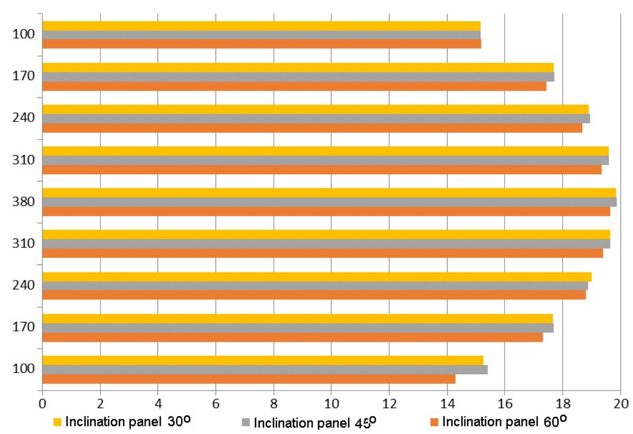

Figure 6. Dependence between Voltage / luminous intensity / angle of incidence

The results presented in Table 5, respectively Figures 7 and 8 have been obtained when the photovoltaic panel is connected to a load (light emitting diode lamp bulbs 12 V).

The results presented in Table 6 and Figures 9 and 10 were obtained in the case where the photovoltaic panel is connected to a load (resistor of 30 ohms).

Table 5. The consumer used is a 12V LED lamp bulbs

No.	Sun incidence angle [°]	Luminous intensity [W/m²]	Voltage on the panel [V]			Current [A]		
			30°	45°	60°	30°	45°	60°
1	60	100	9,58	9,53	9,45	0	0	0
2	45	170	11,59	11,11	10,69	0,04	0,03	0,03
3	30	240	14,40	14,01	12,58	0,08	0,07	0,05
4	15	310	17,36	16,85	14,94	0,13	0,12	0,09
5	0	380	**18,07**	**17,85**	**16,12**	**0,14**	**0,13**	**0,11**
6	-15	310	17,43	17,04	14,92	0,13	0,12	0,09
7	-30	240	14,71	14,01	12,82	0,09	0,07	0,06
8	-45	170	11,50	11,22	10,67	0,04	0,03	0,03
9	-60	100	9,49	9,44	9,36	0	0	0

Table 6. The Consumer used is a 30 ohm resistor

No.	Sun incidence angle [°]	Luminous intensity [W/m²]	Voltage on the panel [V]			Current [A]		
			30°	45°	60°	30°	45°	60°
1	60	100	0,34	0,31	0,26	0	0	0
2	45	170	1,12	1,04	0,80	0,04	0,04	0,03
3	30	240	2,84	1,60	1,88	0,09	0,08	0,06
4	15	310	4,95	4,29	3,01	0,15	0,13	0,09
5	0	380	**6,06**	**5,28**	**3,72**	**0,19**	**0,16**	**0,12**
6	-15	310	5,07	4,49	3,16	0,16	0,14	0,10
7	-30	240	3,12	2,88	2,06	0,10	0,09	0,07
8	-45	170	1,33	1,20	0,88	0,04	0,04	0,03
9	-60	100	0,33	0,31	0,26	0	0	0

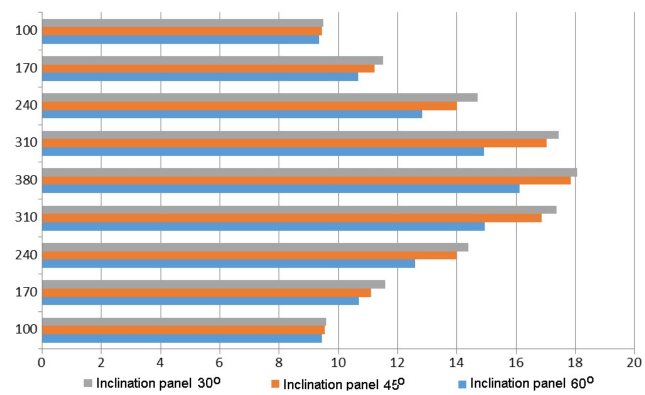

Figure 7. Dependence between Voltage / luminous intensity / angle of incidence

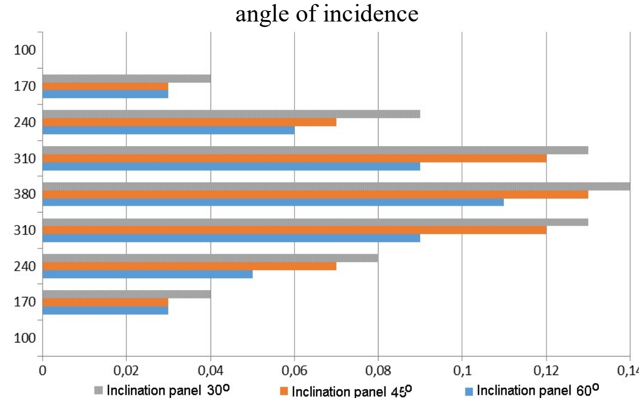

Figure 8. Dependence between Current strength / luminous intensity / angle of incidence

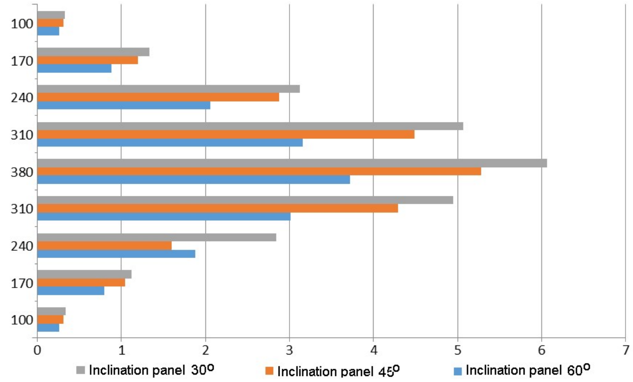

Figure 9. Dependence between Voltage / luminous intensity / angle of incidence

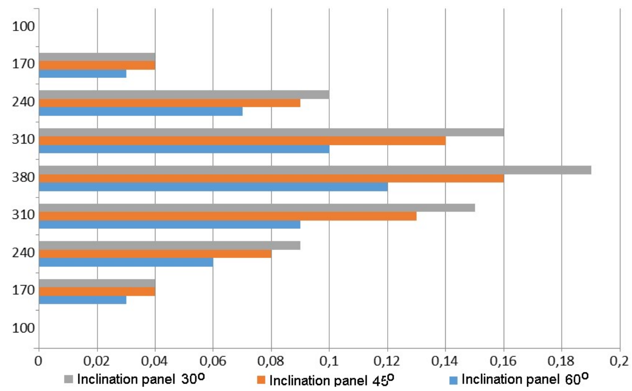

Figure 10. Dependence between Current strength / luminous intensity / angle of incidence

4. CONCLUSIONS

In terms of the efficiency of photovoltaic systems we can be stated:

- For fixed positioning systems, like those studied in this paper, it appears that the best efficiency of a photovoltaic module has the facility when it is set at an inclination of 30°.
- By Increasing the number of photovoltaic units, will entails increasing the amount of electricity delivered to the grid.

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