RESEARCH OF INFLUENCE OF ORIENTATION OF PHOTOVOLTAIC MODULES ON PRODUCTION OF ELECTRIC ENERGY FROM PHOTOVOLTAIC SYSTEMS USING INFORMATION SYSTEM PVGIS-CMSAF

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ABSTRACT:*The report explores the impact of the azimuth angle and tilt of photovoltaic modules on annual electricity generation. The information system PVGIS-CMSAF was used to obtain the annual electricity production at different orientation of photovoltaic modules. The influence of the orientation of the photovoltaic modules on the annual electricity generation is shown in the tables and figures.*

KEYWORDS: *PV Systems, PVGIS-CMSAF, orientation of photovoltaic modules.*

1.INTRODUCTION

It is generally accepted that the optimum angle of inclination of solar panels to achieve maximum annual energy collection is the angle of latitude of the location. If a surface is inclined at an angle equal to the angle of latitude, it will be turned exactly to the Sun at midday on March 21 and September 21. Fortunately, for photovoltaic systems, the captured energy does not change much even with significant deviations from the optimal angle of inclination of the photovoltaic modules and a zero azimuth deviation. This flexibility means that many of the existing buildings have roofs and roof angles suitable for photovoltaic systems.

Access to data from the PVGIS geographic photovoltaic information system makes it possible to find the optimal tilt of the photovoltaic modules and to obtain information about the generated electric energy at different orientation of the photovoltaic modules. Through the data obtained from the PVGIS information system, a table for the influence of the azimuth and tilt of the photovoltaic modules on the generated electric energy for a specific region of Europe.

2.USING OF THE INFORMATION SYSTEM PVGIS-CMSAF FOR RESEARCH THE INFLUENCE OF THE ORIENTATION OF THE PHOTOVOLTAIC MODULES ON THE PRODUCTION OF ELECTRIC ENERGY FROM PHOTOVOLTAIC SYSTEMS

The Photovoltaic Geographic Information System (PVGIS) provides information on solar radiation and geographic assessment available to determine the efficiency of photovoltaic systems. Cards that provide information about solar radiation on a horizontal and sloping surface are used. Data are based on satellite data from 1998-2011. and are in kWh/m^2. The system also gives information on the potential of the generated electricity generated by a photovoltaic system for 1 kWp [3].

The calculations are for Building №1 of the Technical University Gabrovo - Location: 42°52'32" North, 25°18'25" East, Elevation: 502 m a.s.l. Similarly, they can be used for any point in Europe.

3.METHOD FOR DETERMINING THE INFLUENCE OF THE AZIMUTH ANGLE AND THE ANGLE OF THE SLOPING OF THE PHOTOVOLTAIC MODULE ON THE PRODUCTION OF ELECTRIC ENERGY FROM THE PHOTOVOLTAIC SYSTEMS USING THE INFORMATION SYSTEM PVGIS-CMSAF AND THE EXCEL PROGRAM

Collecting the data from the PVGIS information system and processing of the data with the Excel program in the following order:

1. Obtaining information on annual electricity generation at the defined geographic position, angle of inclination and azimuth using the PVGIS information system. Set the losses in % that would be obtained in the cables and the inverter. In the specific case, the Involar Microinverter MAC250A inverter with 95% efficiency is set to lose 6%.

2. Recording the received information for annual electricity generation, heat losses and reflection losses according to the angle of inclination and azimuth in Excel table.

3. Processing of the information for obtaining in percentage of produced electric energy at different orientation of the photovoltaic modules. Making of a table showing annual electricity production from photovoltaic systems with a inclination of 0 ° to 90 ° and azimuth from -90 ° to 90 °.

For the geographic coordinates of Gabrovo, the PVGIS information system provides an optimal tilt of the photovoltaic modules equal to 33˚ and azimuth 0˚ for obtaining maximum year-round quantity of electricity from fixed photovoltaic modules.

Table 1 shows the values in kWh obtained for electricity produced per year at a given geographic position, angle of inclination and azimuth with the PVGIS information system.

Table 2 shows values in% of the electrical energy produced at the orientation of the photovoltaic module, different from an optimal tilt of 33 ° and azimuth 0 °.

Table 1

Electricity produced kWh per year with photovoltaic system 1kWp													
inclination of 0 ° to 90 °													
90	637	712	771	814	840	849	852	845	834	806	762	703	629
80	739	820	887	939	974	991	993	987	968	931	878	811	730
70	832	917	988	1040	1090	1110	1111	1100	1080	1040	979	908	824
60	915	999	1070	1130	1170	1200	1202	1190	1170	1120	1060	990	906
50	984	1070	1130	1190	1230	1260	1266	1250	1230	1180	1130	1060	976
40	1040	1110	1180	1230	1270	1290	1302	1290	1260	1220	1170	1110	1030
33	1070	1140	1190	1240	1280	1300	1308	1300	1270	1240	1190	1130	1070
30	1080	1150	1200	1240	1280	1300	1306	1290	1270	1240	1190	1140	1080
20	1120	1160	1200	1230	1260	1270	1280	1270	1260	1230	1200	1160	1110
10	1140	1160	1180	1200	1220	1230	1230	1220	1220	1200	1180	1160	1140
0	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150
	-90	-75	-60	-45	-30	-15	0	15	30	45	60	75	90
	East						azimuth, °						West

Table 2

% Electricity produced relative to optimal orientation													
inclination of 0 ° to 90 °													
90	48,7	54,4	58,9	62,2	64,2	64,9	65,1	64,6	63,8	61,6	58,3	53,7	48,1
80	56,5	62,7	67,8	71,8	74,5	75,8	75,9	75,5	74,0	71,2	67,1	62,0	55,8
70	63,6	70,1	75,5	79,5	83,3	84,9	84,9	84,1	82,6	79,5	74,8	69,4	63,0
60	70,0	76,4	81,8	86,4	89,4	91,7	91,9	91,0	89,4	85,6	81,0	75,7	69,3
50	75,2	81,8	86,4	91,0	94,0	96,3	96,8	95,6	94,0	90,2	86,4	81,0	74,6
40	79,5	84,9	90,2	94,0	97,1	98,6	99,5	98,6	96,3	93,3	89,4	84,9	78,7
33	81,8	87,2	91,0	94,8	97,9	99,4	100,0	99,4	97,1	94,8	91,0	86,4	81,8
30	82,6	87,9	91,7	94,8	97,9	99,4	99,8	98,6	97,1	94,8	91,0	87,2	82,6
20	85,6	88,7	91,7	94,0	96,3	97,1	97,9	97,1	96,3	94,0	91,7	88,7	84,9
10	87,2	88,7	90,2	91,7	93,3	94,0	94,0	93,3	93,3	91,7	90,2	88,7	87,2
0	87,9	87,9	87,9	87,9	87,9	87,9	87,9	87,9	87,9	87,9	87,9	87,9	87,9
	-90	-75	-60	-45	-30	-15	0	15	30	45	60	75	90
	East						azimuth, °						West

Table 3 shows heat loss values in % of photovoltaic cell as a result of heating the photovoltaic modules. The values are for different orientation of the photovoltaic modules.

Table 3

Heat losses % at different orientation													
inclination of 0 ° to 90 °													
90	10,3	9,5	8,7	8,0	7,3	6,8	6,8	7,1	7,8	8,7	9,6	10,5	11,4
80	10,0	9,5	8,9	8,4	7,8	7,4	7,4	7,7	8,3	9,0	9,8	10,4	11,0
70	9,8	9,5	9,2	8,8	8,4	8,1	8,1	8,3	8,8	9,4	9,9	10,3	10,7
60	9,7	9,5	9,3	9,1	8,8	8,7	8,7	8,9	9,2	9,6	10,0	10,3	10,5
50	9,5	9,4	9,4	9,3	9,1	9,0	9,1	9,2	9,5	9,7	10,0	10,1	10,2
40	9,2	9,3	9,3	9,3	9,2	9,2	9,2	9,3	9,5	9,7	9,8	9,8	9,8
33	9,0	9,1	9,1	9,1	9,1	9,1	9,2	9,3	9,4	9,5	9,6	9,6	9,5
30	8,9	9,0	9,1	9,1	9,1	9,1	9,1	9,2	9,3	9,4	9,5	9,4	9,4
20	8,5	8,6	8,7	8,8	8,8	8,8	8,8	8,9	8,9	9,0	9,0	9,0	8,9
10	8,2	8,3	8,3	8,3	8,4	8,4	8,4	8,5	8,5	8,5	8,5	8,5	8,4
0	8,1	8,1	8,1	8,1	8,1	8,1	8,1	8,1	8,1	8,1	8,1	8,1	8,1
	-90	-75	-60	-45	-30	-15	0	15	30	45	60	75	90
	East						azimuth, °						West

In the southwest orientation of the photovoltaic modules, these values are higher than those in the Southeast orientation. Due to higher air temperatures in the afternoon, the temperatures of the PV modules are higher than before noon and have lower efficiency of the work of the photovoltaic modules.

Table 4 shows reflection loss values in %. The values are for different orientation of the photovoltaic modules on tilt and azimuth.

Table 4

Reflection losses % at different orientation

inclination of 0 ° to 90 °	-90	-75	-60	-45	-30	-15	0	15	30	45	60	75	90
90	4,1	3,9	3,9	4,1	4,6	5,1	5,3	5,1	4,6	4,1	3,9	3,9	4,1
80	3,8	3,5	3,5	3,5	3,8	4,0	4,1	4,0	3,8	3,5	3,5	3,5	3,8
70	3,5	3,3	3,2	3,2	3,3	3,4	3,4	3,4	3,3	3,2	3,2	3,3	3,5
60	3,4	3,1	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,1	3,4
50	3,4	3,1	3,0	2,9	2,8	2,8	2,9	2,8	2,8	2,9	3,0	3,1	3,4
40	3,5	3,2	3,0	2,9	2,8	2,8	2,8	2,8	2,8	2,9	3,0	3,2	3,5
33	3,5	3,2	3,0	2,9	2,9	2,9	2,9	2,9	2,9	2,9	3,0	3,2	3,5
30	3,5	3,3	3,1	3,0	2,9	2,9	2,9	2,9	2,9	3,0	3,1	3,3	3,5
20	3,7	3,4	3,3	3,2	3,1	3,1	3,1	3,1	3,1	3,2	3,3	3,4	3,7
10	3,8	3,7	3,5	3,5	3,4	3,4	3,4	3,4	3,4	3,5	3,5	3,7	3,8
0	3,9	3,9	3,9	3,9	3,9	3,9	3,9	3,9	3,9	3,9	3,9	3,9	3,9
	East						azimuth, °						West

It can be seen from Table 2 that with tilts of photovoltaic modules between 20 and 50 degrees and azimuth between minus 30 degrees and plus 30 degrees the photovoltaic system will work with efficiency over 95%. It is also evident from Table 2 that we have a fairly large area of azimuths and tilts where the photovoltaic system will operate at an efficiency of over 90%.

The level of solar radiation in the winter is less than in the summer. In order to obtain maximum annual electricity, a tilt of less than latitude is used to capture more solar radiation in summer than the winter figure 1.

Using a tilt greater than the optimum provides a more even distribution of the energy received during the year. Figure 1 shows an average daily electricity output per month during the year for tilt angles of the photovoltaic modules 20 ° and 50 ° and azimuth 0 °. To maximize the amount of electrical energy in the winter, the tilt of the photovoltaic module increases due to the lower sun layout in the winter. This is desirable when the requirements for electricity generation in the winter predominate over electricity generation in the summer.

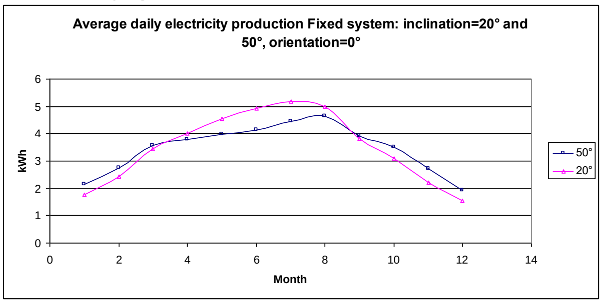

Figure 1. Average daily electricity production by months during the year for tilt angles of the photovoltaic modules 20 ° and 50 ° and azimuth 0 °.

Figure 2 shows an average daily electricity generation per year for sloping angles of the photovoltaic modules 20 ° and 50 ° and azimuth 0 °. The bigger tilt provides more electricity generation at noon. A smaller tilt makes electricity generation more evenly distributed throughout the day.

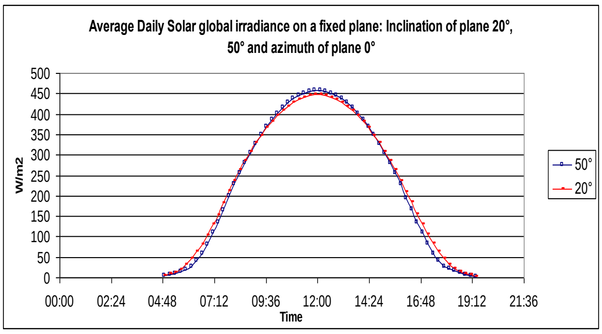

Figure 2. Average daily electricity generation for sloping angles of photovoltaic modules 20 ° and 50 ° and azimuth 0 °.

Figure 3 shows an average daily electricity generation per year for optimal angle of inclination of the photovoltaic modules and azimuth -30 ° and azimuth 30 °. Targeting photovoltaic modules in the southeast provides more electricity before noon. Targeting photovoltaic modules in the southwest provides more electricity after noon.

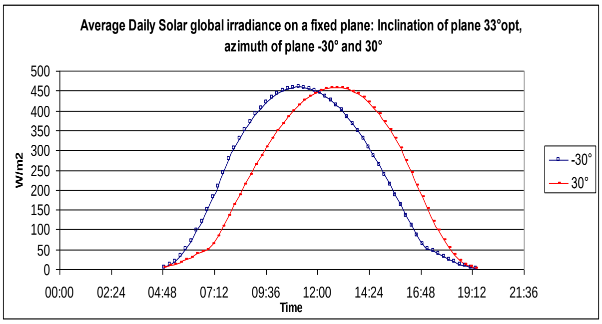

Figure 3. Average daily electricity generation per year for optimal angle of inclination of the photovoltaic modules and azimuths -30 ° and 30 °.

Due to the higher surface temperature of the modules after noon compared to before noon, it is preferable to choose orientation of photovoltaic modules south-east with the aim of producing more electricity. Southwest targeting has an advantage in terms of own consumption, as it is usually more common in households to consume electricity after lunch and before evening.

In Bulgaria, sloping roofs with tiles are predominant. Roof tilts are usually between 22 ° and 45 °. For the geographic latitude of Bulgaria, for the production of electricity with efficiency above 95% compared to the optimal orientation of photovoltaic modules, the tilt of the modules should be between 20 and 50 degrees and an azimuth between minus 30 degrees and plus 30 degrees. Table 2 shows that we have a fairly large tilt and azimuth area where the photovoltaic system located on a sloping roof will operate at an efficiency of over 90% relative to the optimal orientation of the photovoltaic modules.

Table 2 shows that we can use, besides the southern tilt of the roof and the eastern and western tilts. This will result in a more even generation of electricity during the day. Photovoltaic systems located on the eastern and western tilts will operate with an efficiency of more than 80% compared to those located on a southern tilt.

CONCLUSIONS

The method described makes it possible to build Table 2. Table 2 compares the produced electrical energy with a different orientation of the photovoltaic modules with that produced at an optimal tilt and azimuth 0 °.

The data in Table 2 allow for a quick determination of the efficiency of photovoltaic system operation in the orientation of photovoltaic modules different than the optimal.

It can be seen from Table 2 that for the specific geographic location of photovoltaic modules, with a module tilt of -20 ° or + 20 ° relation to the optimum tilt, electricity generation drops to 95% relative to optimal targeting. Also, it can be seen that when the photovoltaic modules are deviated from + 30 ° or -30 ° relation to the azimuth 0 °, the electricity energy output drops to 95% compared to the optimal targeting. From the same table, we see that we have a fairly large area of azimuth and tilts of the modules in which the photovoltaic system will operate at an efficiency of over 90%.

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