COMPARISON AND ASSESSMENT OF ELECTRICITY GENERATION CAPACITY FOR DIFFERENT TYPES OF PHOTOVOLTAIC SOLAR PLANTS OF 1 MW IN SOKOBANJA, SERBIA

by

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This paper gives the results of the electricity generated by the fixed, one-axis and dual-axis tracking photovoltaic solar plant of 1 MW with flat panels made of monocrystalline silicon which is to be built in the area of Sokobanja (spa in Serbia). Further on follows a description of the functioning of the fixed and one-axis and dual-axis tracking solar plants. For the calculation of the electricity generated by these plants PVGIS program was used. Calculations have shown that fixed photovoltaic solar plant power of 1 MW, solar modules of monocrystalline silicon yield 1130000 kWh power output, one-axis tracking solar plant yields 1420000 kWh, and dual-axis tracking solar plant yields 1450000 kWh of electricity. Electricity generated by the fixed photovoltaic solar plant could satisfy 86% of the annual needs for the electricity of the „Zdravljak" hotel and the special "Novi stacionar" hospital in Sokobanja.

Key words: *solar energy, solar cells, fixed photovoltaic solar plant, tracking photovoltaic solar plant*

Introduction

Renewable sources of energy are being widely used worldwide to generate thermal and electrical energy. Serbia bears a great potential for the use of renewable sources of energy out of which for the generation of electricity one mostly uses hydroenergy while the energy of wind, solar energy, geothermal energy, and biomass are scarcely used [1, 2].

Average solar irradiation on the territory of Serbia ranges from 1.1 kWh/m^2 per day on the north to 1.7 kWh/m^2 per day on the south during January, and from 5.9 to 6.6 kWh/m^2 per day during July. On a yearly basis average value of the global solar irradiation for the territory of Serbia ranges from 1200 kWh/m^2 per year in the northwest of Serbia to 1550 kWh/m^2 per year in the southeast of Serbia, while in the middle part it totals to around 1400 kWh/m^2 per year. Due to this Serbia enhances favourable conditions for the use of solar energy and its conversion into the thermal and electrical energy [3, 4].

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For the low temperature conversion of solar energy one uses flat collectors with water or air. For the conversion of solar energy into electricity one uses solar cells made of monocrystalline, policrystalline amorphous silicon and other materials. Solar cells are mostly used for the generation of electrical energy in households in forms of small photovoltaic (PV) solar plant of 1-2 kW on the roofs or the facades of the housing units [5].

From the outbreak of the world economy crisis in 1973s increasing attention is being drawn to the use of solar cells for the electricity generation. Worldwide more than 1000 PV solar plants have been installed of smaller or greater power on the flat surface. Most developed countries regulate legally the possibility of generating and selling of the PV solar plants generated electrical energy. Due to this fact use of solar energy contributes to more efficient use of countries' own potentials in producing electrical and thermal energy, to the reduction of the emission of the green house gases, to the lowering of the import rates and the use of fossil fuels, to the development of the local industries, and the increase of the job openings [6-8].

In Serbia one uses solar irradiation mainly for the heating of water and rarely for the electricity generation. Up to now four PV solar plants were installed in Serbia: on the premises of the elementary school "Dušan Jerković" in Ruma (3 kW, 2004), in the middle school in Varvarin (5 kW, 2010), in the electrotechnical school "Rade Končar" in Belgrade (5 kW, 2010) and in the high technical school "Mihajlo Pupin" in Kula (5 kW, 2010). PV solar plants in Varvarin, Belgrade, and Kula were installed thanks to the donations of the Government of Spain and through the Agency for the Energy Efficency in Belgrade within the Project "Development of the installations for the promotion and use of solar energy in Serbia".

By the decree of the Government of the Republic of Serbia from 2009, electric energy produced in private or state PV solar plant ab to 5 MW and 1 kWh generated power will be sold at 0.23 € in the next 12 years.

In recently published book of the Electric Power Industry of Serbia entitled The White Book of the Electric Power Industry of Serbia one can find legislature of the EU referring to the renewable sources of energy, use of renewable energy in Serbia legal framework, and the possibilities of the use of the renewable sources of energy in Serbia. The book cites the guidelines of the EU envisaging to reduce the greenhouse gas levels by 20%, to reduce energy consumption by 20% and to provide 20% of needed energy from the renewable sources of energy by 2020. Besides, the book mentions that near Čajetina a PV solar plant of 10 MW that would generate annually 14710 MWh will be installed thus providing 2,8% of electrical energy for that area [9].

The paper [10] gives a review of some key issues and prospects related to solar PV power engineering in Serbia. Solar PV energy sector in the Serbia is poorly developed, despite a very good geographical position and recent introduction of feed-in-tariffs (FIT) by the Serbian Government. Apart from that the paper presents the results of the electricity generation calculations for the fixed and tracking PV solar plants by means of PVGIS software in 20 towns in Serbia. The paper concludes that insufficient awareness of the opportunities of solar PV produced electricity may be an obstacle which can significantly limit and delay its use in Serbia. At the moment solar PV technology is not implemented in the Serbian renewable energy source (RES) sector and initiatives to take some firm steps in this direction are expected [10].

Having in mind that up to now no PV solar plant of 1 MW was installed in Serbia this paper will present the results of the comparative study of the electricity generated by the fixed PV solar plant, one-axis and dual-axis tracking PV solar plant of 1 MW in Sokobanja.

Location and climate conditions

Sokobanja is situated in Sokobanja's valley at the 43°39' north latitude and 21°52' of east longitude and 300 m above the see level. Sokobanja is a famous resort having 8407 inhabitants. Sokobanja is renown for its balm and hot springs healing various forms of respiratory deseases. As an acclaimed resort Sokobanja gives priority to the environmental protection. Therefore their communal authorities have in 2000 issued a declaration to pronounce Sokobanja the first ecological commune in Serbia [11].

Among numerous tourist and health objects in Sokobanja special treatment is given to "Zdravljak" hotel spacing 12600 m^2 and the special „Novi stacionar" hospital spacing 8200 m^2. Annualy "Zdravljak" hotel spends 636480 kWh and the special "Novi stacionar" hospital spends 679344 kWh electrical energy.

Entering Sokobanja at the 850 meter on the left on the road leading from Niš to Sokobanja there is a part of Sokobanja known as Ključ that could be a site for the installation of the PV solar plant of 1 MW. The grounds of this site is of the low quality class, is not urbanized and is used for farming purposes. 400 meters from this site there is the main electroline [11].

Sokobanja has a moderate-continental climate with hot summers and mild winters and yearly amplitudes of temperatures up to 23 °C where in pluviometric regime ocassionally mediterannean influences can be found [12].

Average values of the meteorological data of Sokobanja in the period from 1961 to 2010 are shown in tabs. 1 and 2 [12-17].

Table 1. Average values of the meteorological data of Sokobanja in the period from 1961 to 2010

Month	Average air temperature [°C]	Precipitation [mm]	Sunshine duration [hour]		Average humidity [%]	Average overcast [%]
			Daily	Monthly		
January	–1.6	44	2.2	61.7	82	69
February	0.6	42	2.9	80.4	82	66
March	5.0	42	4.2	131.3	77	59
April	10.8	59	5.4	163.4	71	54
May	16.0	71	6.9	211.9	73	51
June	19.2	68	7.9	234.9	75	46
July	20.9	53	8.9	274.2	70	36
August	20.6	45	8.6	267.7	71	30
September	16.3	43	8.3	204.4	75	37
October	10.8	55	4.8	152.7	78	49
November	5.1	61	2.7	82.2	80	66
December	1.2	55	1.6	51.4	83	70

Table 2. Average values of the air temperature [°C] in some seasons in the period from 1961 to 2010 (measuring stations Sokobanja, 300 m above sea level)

Winter	Spring	Summer	Autumn
0.1	10.6	20.2	10.7

As can be seen in tab. 1 that the coldest month in Sokobanja is January with the average temperature from –1.6 °C, and the hottest month is July with the average temperature of 20.9 °C. Maximal precipitation in Sokobanja is in May (71 mm) and June (68 mm), and minimal ones are in September (43 mm) and January (44 mm). Sokobanja has 24.0 snowing days a year with most snowing days in December. Dominant wind in Sokobanja is Košava appearing in spring and autumn and is scarce in summer and winter. The biggest average velocity has the wind coming from the northeast, 3.3 m/s. On a yearly level relative humidity of air in Sokobanja is 76.42%. The biggest overcast is in December, January and February (70%, 69%, and 66%, respectively) and the smallest overcast is in July, August and September (36%, 30%, and 37%, respectively) [12].

Based on the Republic Hydrometeorological Institute of Serbia data in the period 1961-1990 average sunshine duration in Sokobanja valley was 1861 hours with the maximum in July with 267 hours or on average 8.6 hours a day. The lowest sunshine duration was in December with 48 hours or on average 1.5 hours daily, and in January 59 hours or on average 1,9 hours a day. Based on the data from tab. 1 it can be seen that in the period from 1991-2010. there was an increase in sunshine duration on a yearly basis from 1861 hours to 1971.5 hours in relation to the period from 1961-1990 [12-17].

PV solar plants

PV solar plant denotes a plant using solar cells to convert solar irradiation into the electrical energy. PV solar plant consists of solar modules, inverter converting DC into AC and transformer giving the generated power into the grid net. PV solar plant is fully automatized and monitored by the applicable software. PV solar plants mostly use solar modules made of monocrystalline and polycrystalline silicon and rarely modules made of thin film materials such as amorphous silicon, CdTe, and CIS (copper-indium-gallium-selenide, $CuIn_{1-x}Ga_xSe_2$). Efficiency of the monocrystalline silicon solar cells is 15%, of polycrystalline silicon is around 12%, of amorphous silicon is around 5% and from CdTe and CIS is around 8%. Monocrystalline and polycrystalline silicon solar modules are more suitable for the areas with predominantly direct sun radiation, while solar modules of thin film are more suitable for the areas with predominantly diffuse sun radiation [8, 18-21].

Inverter is a device which converts DC generated by PV solar plants of 12 V or 24 V into three phase AC of 220 V. Depending on the design inverter efficiency is up to 97%. When choosing inverter it is to bear in mind the output voltage of the solar modules array, power of the solar modules array, grid net parameters, managing type of the PV solar plant, *etc*. PV solar plants can use larger number of the inverters of smaller power or one or two invertors of greater power.

PV solar plant monitoring system comprises central measuring – control unit for the survailance of the working regime. Monitoring system uses sensors and softwares to obtain the following data: daily, monthly, and yearly production of the electricity, reduction of CO_2, detailed change of the system parameters, recording of the events after the failure, monitoring of the meteorological parameters, *etc*.

PV solar plants in accordance with the power distribution systems legal regulations use transformers by means of which solar energy generated by PV solar plant is given to the power grid [5-7, 18-21].

Schematics of PV solar plant is given in fig. 1.

Practice shows that the energy efficiency of PV solar plant annually decreased from 0.5-1%. The lifetime of PV modules depends on the solar cell technology used as well. For monocrystalline and polycrystalline silicon solar cells most manufacturers give a warranty of 10/90 and 25/80 which means: a 10-year warranty that the module will operate at above 90%

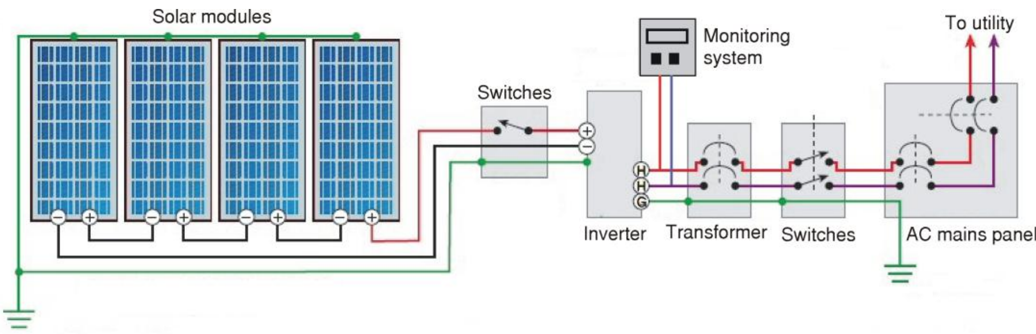

Figure 1. Schematics of a PV solar plant

of nominal power and up to 25 years above 80%. The practical lifetime of the silicon-made PV modules is expected to be at least 30 years [10, 18-20].

PV solar plants represent environmentally clean source of energy. PV solar plant components (solar modules, inverters, monitoring system, conductors, *etc.*) are manufactured by cutting edge, environmentally friendly technologies. PV solar plants operate noiseless, do not emit harmful substances and do not emit harmful electromagnet radiation into the environment. Solar plant recycling is also environmentally friendly. For 1 kWh of PV solar plant generated electrical energy emission of 0.568 kg CO_2 into the atmosphere is reduced. [22, 23].

Fixed PV solar plant

Fixed PV solar plant denotes plant with solar modules mounted on fixed metal supporters under optimal angle in relation to the horizontal surface and all are oriented towards south (fig. 2). To install fixed PV solar plant of 1 MW it is necessary to provide around 20.000 m^2. Maintainence cost of the fixed PV solar plants are much lesser than the maintainence cost of the tracking PV solar plants. Installation costs for the fixed PV solar plant are around 3.5 €/W. Its drawback is in that solar modules do not follow sun radiation so that on the yearly level one does not gain optimal amount of the electricity [8, 21, 24].

Figure 2. Fixed PV solar plant

One-axis tracking PV solar plant

One-axis tracking PV solar plant denotes a plant where solar modules installed under the optimal angle are adapted towards the Sun by revolving around the vertical axis during the day from the east towards the west, following the Sun's azimuth angle from sunrise to sunset (fig. 3). For solar modules revolving electromotors are used using electrical energy from the batteries of the power grid. For the rotor revolving monitoring a centralized software system is used. In case software system fails solar modules can be directed towards the Sun manually. It is also possible to manually set the tilt of the solar modules in relation to the horizontal surface in steps from 5° from 0-45°. One-axis tracking PV solar plant gives the shadow effect of solar modules situated on neighbouring rotors so that for its installation it is necessary to provide around 60000 m^2. Available literature reports the efficiency of one-axis tracking PV solar plant is 20-25% larger than the efficiency of the fixed PV solar plant.

Maintenance costs of the one-axis tracking PV solar plants are much higher than the maintenance costs of the fixed PV solar plants. Installation costs for the one-axis tracking PV solar plant are around 5.5 €/W, which is 30% more than the costs for the fixed PV solar plant. Drawback of one-axis tracking PV solar plant is in that year round there is no automatic adapting of the solar module tilt towards the Sun [19-21, 24-27].

Figure 3. One-axis tracking solar power plant

Dual-axis tracking PV solar plant

Dual-axis tracking PV solar plant denotes a plant where the position of solar modules is adapted towards the Sun by revolving around the vertical and horizontal axis. These PV solar plants follow the Sun's azimuth angle from sunrise to sunset but, they also adjust the tilt angle to follow the minute-by-minute and seasonal changes in the Sun's altitude angle. Solar modules are oriented towards the Sun by means of the appropriate electromotors. Photo sensors mounted on the array send signals to a controller that activates the motors, causing the array angles to change as the Sun's altitude and azimuth angles change during the day. Efficiency of the dual-axis tracking PV solar plant is 25-30% bigger than the efficiency of the fixed PV solar plant. For the installation and function of dual-axis tracking PV solar plant a substantially bigger surface is necessary than for the fixed PV solar plant.

Maintenance costs of dual-axis tracking PV solar plants are higher than the maintenance costs of one-axis tracking PV solar plants. Installation costs for the dual-axis tracking PV solar plant are around 7.5 €/W, which is 47% more than the costs for the fixed PV solar plant [19-21, 24-27].

When designing a large PV solar plant it is very important to optimize energy yield and occupation of land. The paper [28] gives original simulation tool with the appropriate models to calculate the energy yield for different PV solar trackers with a flat PV module grid-connected system. Based on this, the relationship between the yearly average gains and land occupation has been analyzed for several tracking strategies and it is found that the energy gains associated to one north-south axis tracking referenced to static surfaces, ranges from 18% to 25%, and from 37% to 45% for the dual-axis tracker for reasonable ground cover ratios [28].

Until December 2008 Spain installed 2382 MW, Germany 698 MW, USA 260 MW, Korea 100 MW, Italy 70 MW, Portugal 60 MW, and other countries 102 MW PV solar plants. Worldwide more fixed than tracking PV solar plants were installed [29].

PVGIS

PVGIS (*Photovoltaic Geographical Information System* – PVGIS © European Communities, 2001-2008) is a part of the SOLAREC action aimed at contributing to the implementation of renewable energy in the EU. SOLAREC is an internally funded project on PV solar energy for the 7th Framework Programme, PVGIS has been developed at the JRC (Joint Research Centre) of the European Commission within its Renewable Energies Unit since 2001 as a research GIS oriented tool for the performance assessment of solar PV systems in European geographical regions. From the very start of its functioning PVGIS was envisaged to be locally used, however access to the PVGIS database and estimations was drawn as open system access for professionals and the general European public as well by means of the web-based interactive applications. PVGIS provides data for the analysis of the technical, environmental, and socio-economic factors of solar PV electricity generation in Europe and supports systems for EU countries solar energy decision-makings.

PVGIS methodology comprises solar radiation data, PV module surface inclination and orientation, and shadowing effect of the local terrain features (*e. g.* when the direct irradiation component is shadowed by the mountains), thus PVGIS represents immensely important PV implementation assessment tool that estimates dynamics of correlations between solar radiation, climate, atmosphere, the Earth's surface and the PV technology used. Several fast web applications enable an easy estimation of the PV electricity generation potential for selected specific locations in Europe [10, 30].

In order to calculate electricity generated by the fixed PV solar plants, one-axis and dual-axis tracking PV solar plants today PVGIS software packages easily found on the Intenet are used [30, 31]. These programmes can produce the following data: average daily, monthly, and yearly values of the solar irradiation taken on square meter of the horizontal surface or the surface tilted under certain angle in relation to the horizontal surface, change in the optimal tilting angle of the solar modules during the year, relation of global and diffused sun radiation, average daily temperature, and daily, monthly, and yearly electricity generated by the fixed PV solar plants, one-axis, and dual-axis tracking PV solar plants, *etc*. A tipical PVGIS value for the performance ratio (PV system losses) of PV solar plants with modules from monocrystalline and policrystalline silicon is taken to be 0.75 [10, 30]**.**

Results and discussion

This section will interpret the results obtained upon the study of the electricity generated by fixed PV solar plants, one-axis and dual-axis tracking PV solar plants of 1 MW with monocrystalline silicon solar modules in the area of Sokobanja processed by the software cited in the literature [30]. This programme shows that the temperature losses of the plant are 9.7%, that losses due to solar irradiation reflection are 2.9% and that losses on conductors, inverters, in junction boxes are 14%, *etc*.

This programm gives a map which when appears activates the programme, spots the location of the PV solar plant to be, sorts out the type of solar cells and inputs the power and type of PV solar plant (fixed, one-axis and dual-axis tracking PV solar plants).

Graphics of the ratio of diffused and global solar radiation for Sokobanja during the year is given in fig. 4.

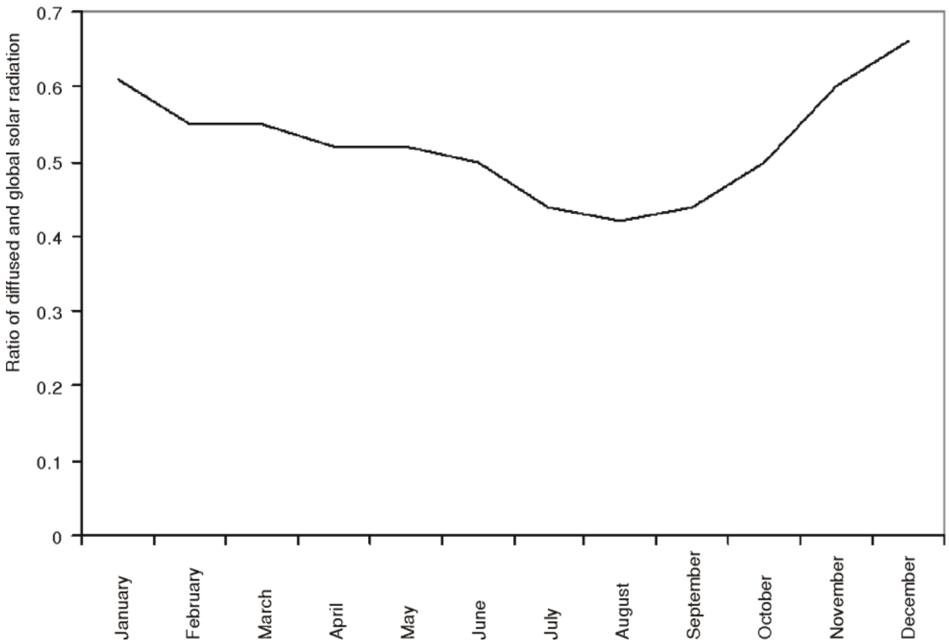

Figure 4. Graphics of the ratio of diffused and global solar radiation for Sokobanja during the year

Graphics show that the portion of diffused in the global solar radiation is decreasing from January till August, and is increasing from September till December. Calculations show that the average value of the ratio of diffuse and global solar radiation during the year is 0.5258 (52.58%). These results are congruent with the results shown in tab. 1 that refers to the degree of overcast in the course of the year in Sokobanja: average value of the overcast in the course of the year is 52.75% and average value of the ratio of diffuse and global solar irradiation during the year for Sokobanja is 52.58 %.

Graphics of the change in optimal angle of solar moduls for Sokobanja during the year is given in fig. 5.

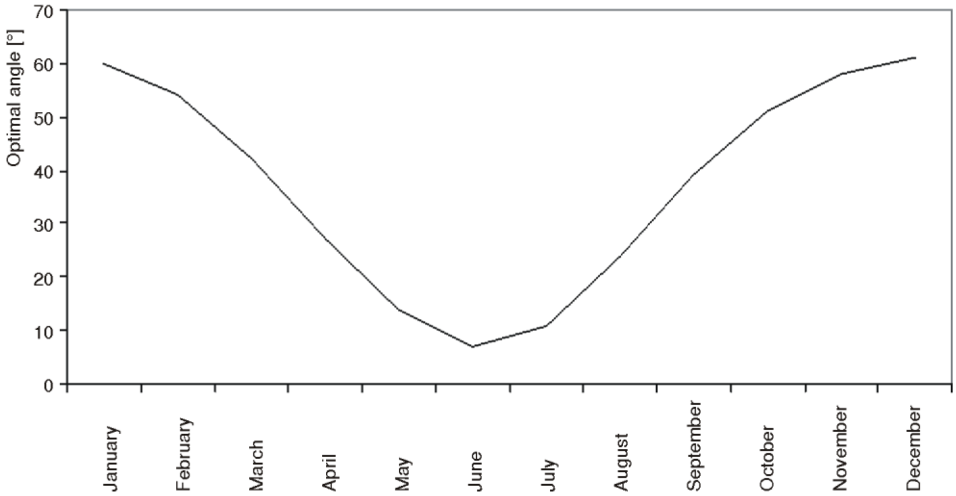

Figure 5. Graphics of the change in optimal angle of solar moduls for Soko banja during the year

Change in optimal angle of solar moduls is caused by the change of the Sun's height during the year. Calculations have shown that the optimal angle of solar moduls in fixed PV solar plant year round is 33° in relation to the horizontal surface.

Solar irradiation on the horizontal and optimally inclined sufrace obtained by PVGIS for Sokobanja is shown in tab. 3.

Table 3. Solar irradiation on the horizontal and optimally inclined sufrace obtained by PVGIS for Sokobanja

Month	Solar irradiation on the horizontal sufrace (0°) [$kWhm^{-2}$ per day]	Solar irradiation on the optimally inclined sufrace (33°) [$kWhm^{-2}$ per day]
January	1380	2090
February	2140	2980
March	3220	3900
April	4450	4800
May	5310	5230
June	5920	5590
July	6310	6100
August	5580	5890
September	4150	4990
October	2740	3740
November	1580	2310
December	1120	1700
Year	3670	4110

Based on the obtained data tab. 3 shows that solar irradiation on the optimally inclined surface (33°) is by 10.7% bigger than the solar irradiation on horizontal surface annually.

Results of the calculations for the average daily, monthly, and yearly sum of global solar irradiation per square meter received by the modules of the given PV systems (fixed PV solar plants, one-axis, and dual-axis tracking PV solar plants) of 1 MW in Sokobanja are given in tab. 4.

Table 4. Results of the calculations for the average daily, monthly and yearly sum of global solar irradiation per square meter received by the modules of the given PV systems (fixed PV solar plants, one-axis and dual-axis tracking PV solar plants) of 1 MW in Sokobanja

Month	Fixed PV solar plant of 1 MW (optimal inclination of modules is 32°, orientation (azimuth) = 0°)		Inclined one-axis tracking PV solar plant of 1 MW (optimal inclination is 35°)		Dual-axis tracking PV solar plant of 1 MW	
	Average daily sum of global solar irradiation per square meter received by the modules of the given system [kWhm^{-2}]	Average sum of global solar irradiation per square meter received by the modules of the given system [kWhm^{-2}]	Average daily sum of global solar irradiation per square meter received by the modules of the given system [kWhm^{-2}]	Average sum of global solar irradiation per square meter received by the modules of the given system [kWhm^{-2}]	Average daily sum of global solar irradiation per square meter received by the modules of the given system [kWhm^{-2}]	Average sum of global solar irradiation per square meter received by the modules of the given system [kWhm^{-2}]
January	2.07	64.2	2.44	75.7	2.46	76.4
February	2.97	83.1	3.54	99.1	3.56	99.7
March	3.89	121	4.73	147	4.76	148
April	4.80	144	5.97	179	6.06	182
May	5.25	163	6.67	207	6.86	213
June	5.62	168	7.48	224	7.77	233
July	6.12	190	8.30	257	8.60	267
August	5.90	183	7.69	238	7.86	244
September	4.98	149	6.38	191	6.49	195
October	3.72	115	4.56	141	4.60	143
November	2.30	69	2.71	81.4	2.73	81.8
December	1.69	52.3	1.98	61.4	2.00	61.9
Yearly average	4.11	125	5.21	159	5,32	162
Total for year	1500		1900		1940	

Graphics of the electricity generated yearly by the fixed PV solar plant (optimal inclination of solar modules is 32°), inclined one-axis tracking PV solar plant (optimal inclination of solar modules is 35°), and dual-axis tracking PV solar plant of 1 MW in Sokobanja is given in fig. 6.

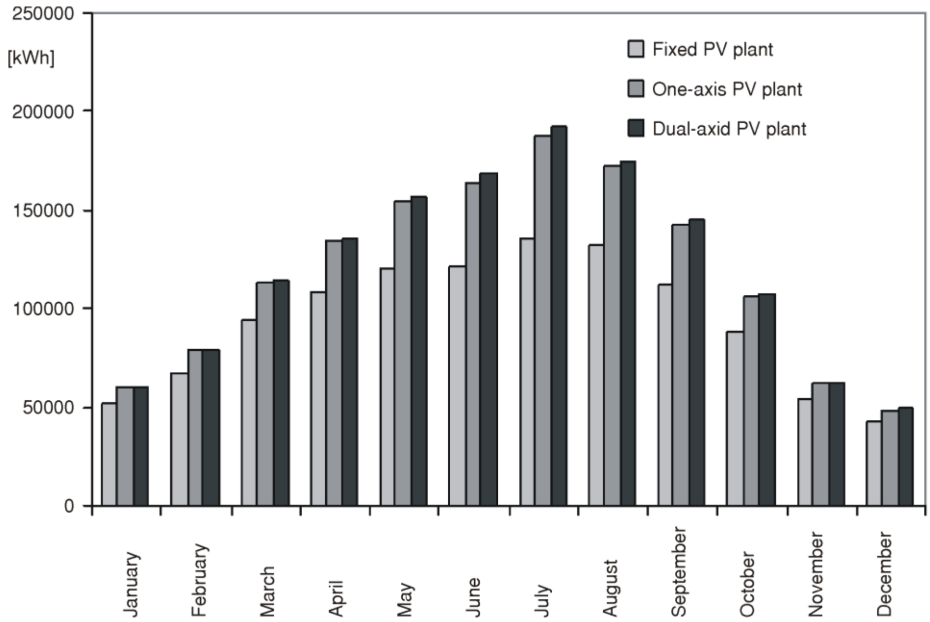

Figure 6. Graphics of the electricity generated yearly by the fixed PV solar plant (optimal inclination of solar modules is 32°), inclined one-axis tracking PV solar plant (optimal inclination of solar modules is 35°), and dual-axis tracking PV solar plant of 1 MW in Sokobanja

Figure 6 shows that the biggest yield of the electrical energy monthly is one generated by the dual-axis tracking PV solar plant, somewhat smaller yield is gained by the inclined one-axis tracking (optimal inclination of solar modules is 35°) and the smallest yield is gained by the fixed PV solar plants of 1 MW with monocrystalline silicon solar modules on optimally inclined surface (32°) in Sokobanja.

Graphics of the electricity that can be generated by the fixed PV solar plant (optimal inclination of modules is 32°), inclined one-axis tracking (optimal inclination of modules is 35°), and dual-axis tracking PV solar plants of 1 MW in Sokobanja is given in fig. 7.

On the basis of the obtained results one can conclude that by one-axis tracking PV solar plant one can get 20.42% and by dual-axis tracking PV solar plant 22.06% more electrical energy in comparison to the fixied PV solar plant of 1MW.

Investment costs and return of the invested funds

To install fixed PV solar plant, one-axis tracking PV solar plant, and dual-axis tracking PV solar plants of 1 MW one needs around 3500000, 5500000, and 7500000 €, respectively. In Sokobanja by fixed PV solar plant of 1 MW one can generate 1130000 kWh, by one-axis tracking PV solar plant of 1 MW one can generate 1420000 kWh, and by dual-axis tracking PV solar plant of 1 MW one can generate 1450000 kWh of electric energy.

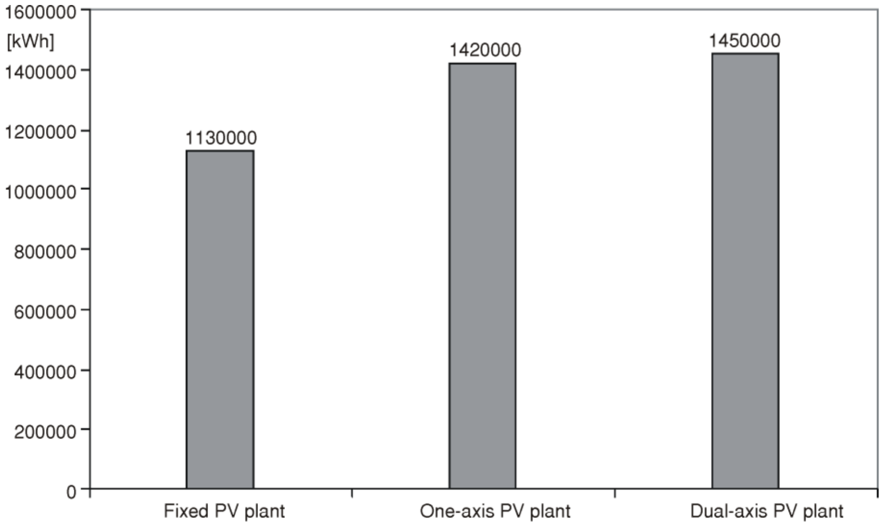

Figure 7. Graphics of the electricity that can be generated by the fixed PV solar plant (optimal inclination of modules is 32°), inclined one-axis tracking (optimal inclination of modules is 35°), and dual-axis tracking PV solar plants of 1 MW in Sokobanja

If one does not include the maintenance expenditures in case of fixed PV solar plants of 1 MW in Sokobanja the invested funds would be according to the current prices for 1 kWh of solar electricity in Serbia, returned in 13.47 years; for one-axis tracking PV solar plant of 1 MW this could be done in 16.84 years, and for dual-axis tracking PV solar plant in 22.49 years. If in tracking PV solar plants one calculates their maintenance costs return of the funds would take longer than before mentioned.

Conclusions

Based on all the above said it is evident that fixed and tracking PV solar plants are increasingly used worlwide. Up to now four PV solar plants were installed in schools in Ruma, Varvarin, Belgrade, and Kula in Serbia. Government decree of the Republic of Serbia envisages private or state investors in Serbia can install PV solar plants of up to 5 MW. Serbia has no PV solar plants of 1 MW. Sokobanja, as a famous spa that pays cosiderable attention to the environmental protection and according to its morphological characteristics and climate parameters is quite convenient for the installation of PV solar plant. Installation of PV solar plant in Sokobanja would contribute to the environmental protection and electricity supply for the local inhabitants.

Based on the results obtained in this paper one can conclude that average ratio of diffuse and global solar radiation in Sokobanja during the year is around 0.5258; that the optimal angle of monocrystalline silicon solar modules in fixed is 32° and in one-axis tracking PV solar plant is 35°; that during the year on one square meter of monocrystalline silicon solar modules (optimal inclination of modules is 32°) in fixed PV solar plant sum of global solar irradiation intake is 1500 kWh, in inclined one-axis tracking PV solar plant (optimal inclination of modules is 35°) sum of global solar irradiation intake is 1900 kWh, and in dual-axis tracking PV solar plant sum of global solar irradiation intake is 1940 kWh. On a yearly basis by fixed PV solar plant one can generate 1130000 kWh, by means of one-axis tracking PV solar plant 1420000 kWh, and by dual-axis tracking PV solar plant 1450000 kWh of electricity. Results show that by one-axis tracking PV solar plant one gets 20.42% more electricity in comparison to the fixed PV solar plant. In case of dual-axis tracking PV solar plant one gets 22.06% more electricity in comparison to the fixed PV solar plant. Fixed PV solar plant of 1 MW with monocrystalline silicon solar modules could satisfy 86% of the yearly needs for the electrical energy of the "Zdravljak" hotel and special "Novi stacionar" hospital in Sokobanja.

According to the current costs in the world, installation costs of the fixed PV solar plant of 1 MW amount to 3500000 €, one-axis tracking PV solar plant 5500000 € and dual-axis tracking PV solar plant 7500000 €. According to the current selling price of kilowat hour of the electricity generated by PV solar plant in Serbia invested funds in the installation of the fixed PV solar plant would be regained in 13.47 years, and in one-axis tracking PV solar plant and dual-axis tracking PV solar plant in 16.84 and 22.49 years, respectively.

Having in mind that tracking PV solar plants are much more expensive than the fixed ones, that they require more space and more funds to maintain them in comparison to the fixed PV solar plants, we think that Sokobanja would be most economical place to install the fixed PV solar plants. Fixed PV solar plant of 1 MW in Sokobanja would have a positive impact on air quality change, as envisaged annual electricity production of 1130000 kWh to reduce CO_2 emissions in the amount of 641840 kg per year.

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