Calculation of PVGIS Solar Data for the Territory of Serbia

Dušan Ž. Djurdjević[1]

Abstract – **In this paper data for annual solar irradiation and potential power production by PV power installations for the territory of the Republic of Serbia is calculated by using the PVGIS interactive on-line calculator. The calculations performed can serve as a helpful guide for initial practical activities in the Serbian PV power engineering field.**

Keywords– **Renewable energy sources (RES), Photovoltaics (PVs), Serbia, PVGIS.**

I. INTRODUCTION

Threads of the global climate changes and environmental pollution due to the use of conventional energy sources have enhancedresearch in the field of the renewable energy sources (RES). Photovoltaic (PV) solar electricity generation iscertainly the most attractive method and possibility to solve global energy problem in the world-wide scale. As the direct energy conversion technology, PV solar power systems are noiseless and environmentally almost completely friendly, having a huge potential to win the race with the traditional energy sources and other RES possibilities.

Various PV estimation tools offer solar radiation and other climatic data useful for an assessment of the PV potential for specific location world-wide: European Solar Radiation Atlas (ESRA), SoDa, NASA SSE, Meteonorm, NREL – US dynamic solar atlas, etc. One of the most popular and easy-accessible solar resource and tools for an assessment of PV potentials and systems is PVGIS© [1]. Amongst other solar radiation databases, PVGIS has advantages as an open data and software PV estimation tool with an excellent geographical grid resolution (1km x 1km) and map based user-friendly interface, providing easy-understandable information for PV geographical assessments. The estimated accuracy of PVGIS calculations is proven to be within several percents [2]. Detailed geographical, climatic and other data make PVGIS on-line calculator ideally suited, not only for non-professionals and initial PV system estimations, but also even for serious PV systems design as part of the integrated management of distributed energy generation, for specifically selected locations in Europe, and most recently for Africa, as well.

In this paper maps of average solar irradiation and solar data for the specificlocation within territory of Serbia arranged by using PVGIS © on-line interactive calculator [1] are presented and discussed.More extensive analysis and results about practical data for solar irradiation and estimated power production by a PV system set up within the Serbian territory can be found in [3]. Although utilization of RES in Serbia is so far limited to micro and mini hydro power-plants, Serbia has large unused potential for production of energy from RES [4] (biomass and biogas resources, geothermal, wind energy potential, non-utilized hydro-power potential and solar energy resources).

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II. 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, [5]. 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. At the very beginning PVGIS was planned to be an in-house decision support system, fortunately access to the PVGIS database and estimations has been made freely available to professionals and the general European public through web-based interactive applications. PVGIS is aimed at providing data to analyse the technical, environmental and socio-economic factors of solar PV electricity generation in Europe and to support systems for policy-making in EU countries. More about PVGIS and the data sources and methodology used can be found on the PVGIS official web-site [1] and references [2,3,6-8].

PVGIS methodology takes into account not only solar radiation data, it considers 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), therefore PVGIS is a powerful PV implementation assessment tool that takes into account the dynamic nature of interactions between solar radiation, climate, atmosphere, the earth's surface and the PV technology used. Several fast web applications (written in C language) enable an easy estimation of the PV electricity generation potential for selected specific locations in Europe.

In [3] PVGIS interactive on-line calculator is used to calculate the yearly total of solar irradiation and PV power estimation for the territory of Serbia for PV modules placed in horizontal (e.g. roofs), vertical (e.g. south-facing buildings facades) and optimally-inclined planes (for maximizing solar energy harvesting in grid-connected PV power plants). Some results of analysis performed in [3] are presented here.

A typical PVGIS value for the performance ratio (PV system losses) of PV systems with modules from mono- or polycrystalline silicon [9,10] is taken to be 0.75, [1,6].

In this paper the version PVGIS-3 is used. The PVGIS-3 data set is based on measurements made on the ground in the period 1981-1990 which are then interpolated between points to get radiation values at any point. A new version PVGIS-CMSAF has been recently introduced which uses the new databases for the solar radiation data provided by the Climate Monitoring Satellite Application Facility (CMSAF) from the period 1998-2010, [1]. According to the possible wrong terrestrial measurements and to the fact that the amount of solar radiation has increased over Europe in the last 30 years, calculations with new PVGIS-CMSAF give higher values than with the older PVGIS-3. For the territory of Serbia PVGIS-CMSAF gives up to 5% higher values for the solar irradiation data.

III. PVGIS Data and Solar Maps for the Territory of Serbia

PVGIS interactive on-line calculator is used to calculate the yearly total of solar irradiation and PV power estimation for the territory of Serbia for PV modules placed in optimally inclined and oriented plane (giving the"optimal" solar irradiation for maximizing solar energy harvesting) and two-axis sun-tracking PV systems.

Fig. 1 shows PVGIS calculated data for average yearly values of total global irradiation in optimally inclined planes in kWh/m^2 for the territory of Serbia. It is clear from Fig. 1 that average solar irradiation is not dependent on geographical latitude only. There are regional differences in global irradiation due to terrain features and climatic conditions.

The properties of the Serbian territory from the point of view of PV utilization are [3,11]:

- Serbia belongs to the South-Eastern European region with a diverse landscape and mainly continental climate with hot and often rainless summers, but windy and snowy winters.
- Yearly sum of "optimal" total solar irradiation for the territory of Serbia varies from 1380 kWh/m^2 in the north up to 1720 kWh/m^2 in the south.
- Serbia has some territorial units with favourable climatic conditions but mainly good conditions for solar PV electricity production.
- Serbia can be divided in the three main regions in respect to the level of the yearly sum of "optimal" total solar irradiation: 1) *Northern and easternmost regions* (about 25% of Serbia) with the "optimal" total solar irradiation less than 1500 kWh/m^2; 2) *Central region*(about 60% of Serbia) with the "optimal" total solar irradiation within a range of 1500 kWh/m^2 to 1600 kWh/m^2; and 3) *South-eastern region*(about 15% of Serbia) where the "optimal" total solar irradiation exceeds 1600 kWh/m^2.
- The seasonal variation of PV electricity yields is significant for the territory of Serbia, with November, December and January being the worst and July and August the best months for PV electicity harvesting (about 3 times better sunny conditions during summer months).

A summary of conclusions on the basis of PVGIS data analysis for the territory of Serbia is:

- The optimum inclination angle of south-facing PV modulesis mainly 33^0 to 35^0.
- Significant daily variations in solar radiation and seasonal horizon-heights of the sun's position in the skysuggest that the sun-tracking PV systems could be considered as the favourable solution in Serbia for PV investments in the future.
- For a performance ratio of the PV system at 0.75 and a PV module conversion efficiency of 15%, the required area for 1kW of installed PV power is about 9 m^2 (around 3.0 m x 3.0 m). It means that in real circumstances in Serbia, market available standard PV equipment assembled from fixed optimally inclined and oriented PV modules and mounted on area of about 9 m^2 (installed PV power of 1kW) harvests on average between 1150 kWh and 1200 kWh of electricity annually, while the daily average value is about 3.2 kWh.
- Grid-connected PV solar systems with optimally inclined and oriented PV modules and with 1kW of installed PV power could yield on average: 1550 kWh x 0.75 x 23 c€/kWh $\simeq$ 270 € annually. For a guaranteed period of 12 years it is nearly 3,300 €.Feed-in tariff (FIT) rate for PV produced energy from 23 c€/kWh is adopted in calculation.
- A two-axis sun-tracking PV solar system with installed 1kW could yield 30% to 35% more money, on average $\simeq$ 360 € annually or for a guaranteed period of 12 years about 4,300 €.

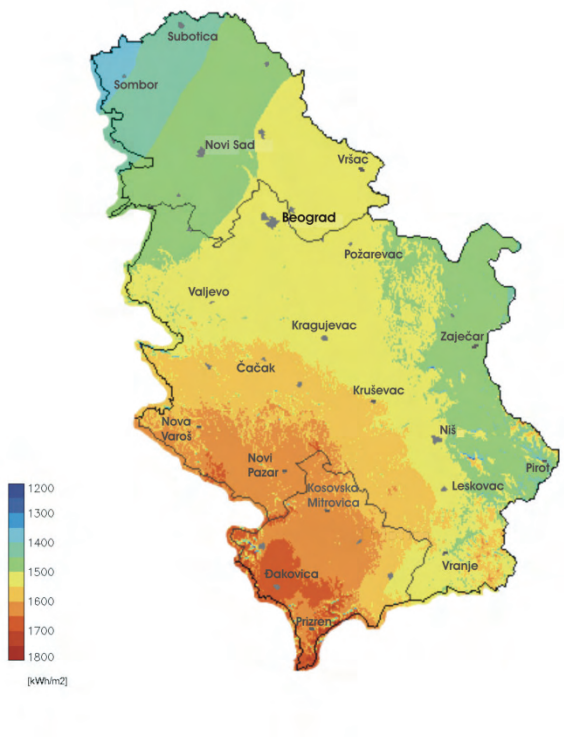

Fig. 1. Yearly sum of total solar irradiation incident on optimally inclined south-oriented PV modules in kWh/m^2 for the territory of Serbia. Adapted for Serbia from PVGIS © European Communities, 2001-2008,http://re.ec.europa.eu/pvgis/, [1,3].

Table 1 gives a daily average of possible PV electricity production in Serbia during a year for fixed optimally inclined and two-axis sun-tracking PV systems [1,3,11]. It is obvious that the central and the south-western parts of the Serbian territory have slight advantage for PV energy harvesting.

TABLE I
AVERAGE VALUES OF POSSIBLE PV ELECTRICITY PRODUCTION FOR THE SERBIAN TERRITORY

Relative location in Serbia	Yearly average values of PV electricity production per day, [kWh/day]	
	fixed optimally inclined PV systems	two-axis sun-tracking PV systems
Farthest North	3.0	3.9
North	3.1	4.1
Farthest South-East	3.1	4.0
South-East	3.2	4.2
Central	3.2	4.3
South-West	3.4	4.5
Farthest South-West	3.5	4.7

IV. PVGIS CALCULATED DATA FOR THE CITY OF NIŠ (SOUTH-EAST REGION OF SERBIA)

For the host city of the ICEST-2011 Conference, the city of Niš,which is located in the south-east region of Serbia (latitude: 43°18'59" North, longitude: 21°53'59" East), some illustrative PVGIS calculations are given in Figs. 2 to 6.The optimum inclination angle of south-facing PV modulesis calculated to be 32^0 with relative orientation -3^0.

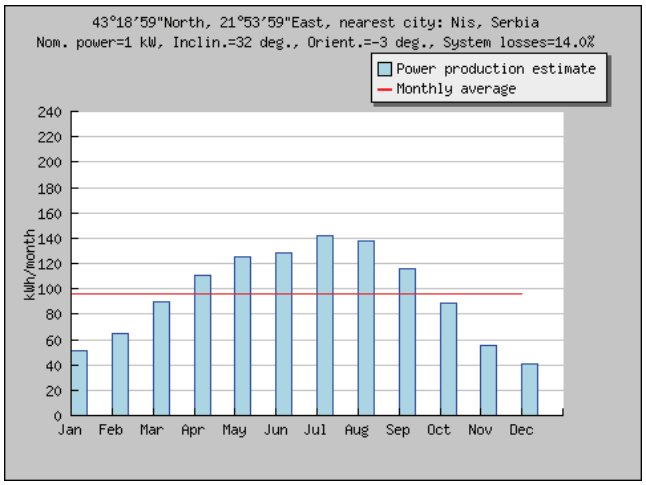

Fig. 2. PVGIS calculation of the estimated amount of electric power which can be expected each month from a PV system with nominal installed power of 1 kW, with stationary PV modules placed in an optimally inclined and oriented plane, placed in the city of Niš, [1].

There are many other aspects which have to be considered in a PV assessment analysis of the specific location planned for setting up the PV power system. Some of them, like surface inclination and orientation, shadowing effect of the local terrainfeatures (e.g. mountains), etc., are incorporated in PVGIS software already. However, possible shadowing effect of the local urban features (e.g. buildings), winter and snow lasting conditions, local pollution and dust conditions (e.g. the vicinity of highways and factories as possible dust sources), etc., have to be carefully analyzed for particular location.

It is important to highlight that besides solar irradiation parameters calculated for the specific location, there are other parameters which have to be taken into consideration within a feasibility study of setting up a grid-connected solar PV system in Serbia [3], such as: technical parameters of the planned solar PV modules and panels, the market prices of solar PV equipment, the cost of design, mounting and maintenance of a solar PV system, and eventually the Government driven RES policy parameters, [3,12,13].

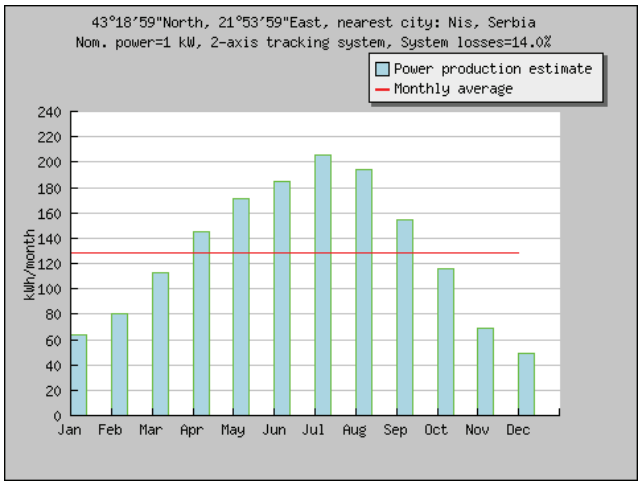

Fig. 3. PVGIS calculation of the estimated amount of electric power which can be expected each month from a PV system with nominal installed power of 1 kW, with a two-axis sun-tracking PV system, placed in the city of Niš, [1].

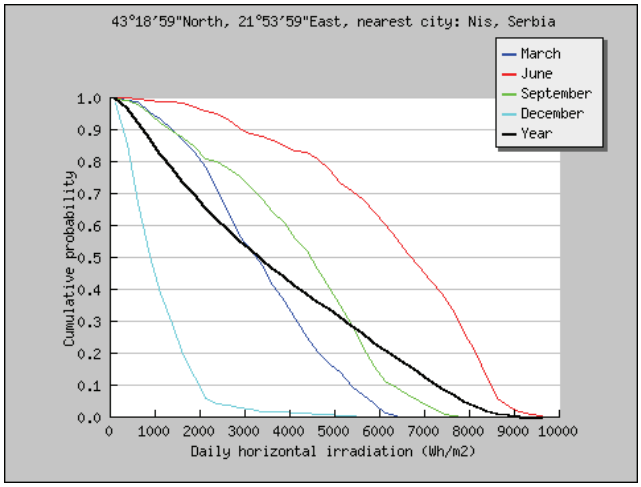

Fig. 4. Probability distribution of daily horizontal solar irradiation,in Wh/m^2, for the city of Niš, [1].

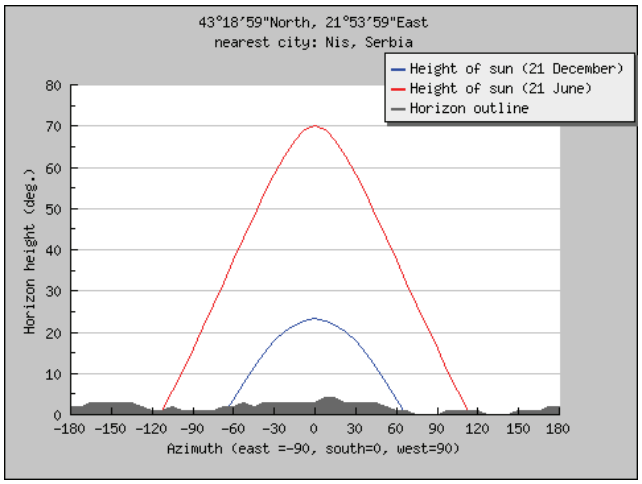

Fig. 5. Seasonal positions of the sun in the sky above the city of Niš during 21st December (the "worst" month and day for the PV electricity production) and 21st June (the "best" month and day for the PV electricity production), [1].

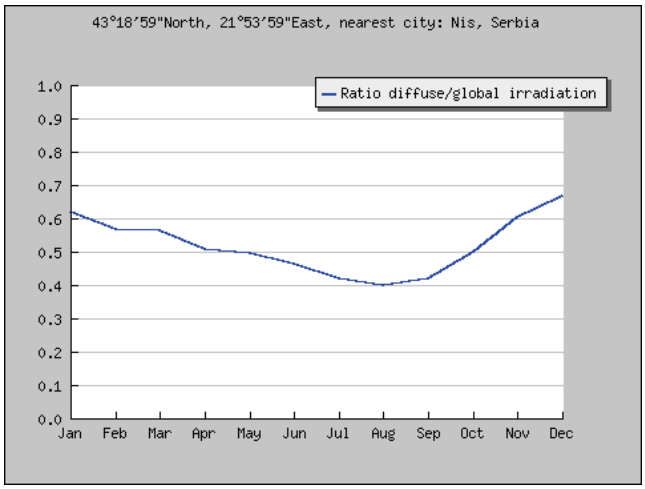

Fig. 6. The ratio between the diffuse component and global solar irradiation for the location of the city of Niš,[1].

V. Conclusion

PVGIS based maps and data for average annual solar irradiation for the specific location within the territory of Serbia are presented and analysed in order to achieve useful details and assessment for the potentials for solar PVs utilization in Serbia. The PVGIS figures and tables (some examples are presented in this paper) can serve as guidelines for the basic necessary data for solar radiation and design of PV grid-connected systems in the Republic of Serbia.

The results obtained from the PVGIS database and on-line calculator can differ from those provided by other providers of solar PV data. For detailed and much more trusted data one has to compare PVGIS calculations with data offered by other similar services. It is obvious that every serious investor in PV power engineering in Serbia would take into consideration data from several databases from different specialized companies.

The overall conclusion is that the Republic of Serbia has the favourable solar irradiation and climatic conditions for solar PV electricity generation; hence the utilization of solar PV electricity generation in Serbia has to be almost certainly expected in the future.

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