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Comparison of predicted and real parameters of PV systems in the Czech Republic and Spain

T. Olšan[1], B.M. Soucase[2] and M. Libra[1]

[1]Czech University of Life Science, Kamycka 129, CZ16521 Prague, the Czech Republic
[2]Universitat Politecnica de Valencia, Camino de Vera, Applied Physics, ES46022 Valencia, Spain
[*]Correspondence: tolsan@email.cz

Abstract. This paper compares predicted performance by a simulation software for a given new constructed PV system of crystalline silicon technology located in Prague with 10 kWp peak power and a similar system in Spain. Simulation software used for the sake of this paper was publicly available PVGIS from the website of its creators, parameters were set to be the same like in the real PV system. The difference between the predicted and the real data was calculated and then discussed in the result section of this paper. Suggestion how to increase the accuracy of the prediction by the simulation software is in the discussion part of this paper.

Key words: PV systems, PVGIS, PV simulation, predicted and real data comparison.

INTRODUCTION

The European Union wants to have 20% of their energy demand covered by the renewable sources by the year 2020. This plan was proposed in 2008. Different countries have different goals, for the Czech Republic that goal is 13% of renewables by the year 2020 and for the Spain that goal is 20% by the same year.

To reach this goal, several countries in EU started subsidy policy on renewables to increase the demand for renewable sources, so renewable sources will be more affordable. This resulted in solar and wind industry boom in those countries with this policy, including both Spain and the Czech Republic. Thanks to this, the Czech Republic already fulfilled its goal in 2014 when renewables covered 13.4% of energy demand. But this subsidy policy was later cancelled in both the Czech Republic and Spain.

In the case of the Czech Republic, the return of investment into photovoltaic (PV) systems was around 7 years when the subsidy policy of government guaranteed the higher price for an electricity generated and then distributed to a grid by a renewable source. Subsidy policy ended in the Czech Republic on 1.1. 2011 and ever since new PV systems were mainly small rooftop installations.

With some of the advance in PV technology, increased lifespan and especially increased the efficiency of PV cells, solar panels will be again interesting technology to invest in on a big scale as far north as the Czech Republic even without subsidy from the government. Therefore, it is helpful to have a software to predict a performance of a PV system and so return of investment.

There are more PV simulations available online for free, namely PVGIS, RETSCreen, and PVWatts. Tho PVGIS design is plain and it can appear difficult for the beginners to use, it provides the best yearly estimate (Psomopoulos et al., 2015). These simulations can be used to predict the performance of the PV systems in the long run, one way how to predict weather pattern in a short term is described in (Rezk et al., 2015).

Such a prediction can be not only useful to help reach certain environmental goals but it is also important for developing countries who struggle to supply electricity in the remote areas to see if its economically viable to build off grid solar power plants in these areas (Ajan et al., 2003). A case study of a PV system in Ivory Coast is done in (Guaita-Pradas, Soucase & Aka 2015). A comparison of PV system cost and payback time in India and Pakistan is in (Guaita-Pradas, Ullah & Soucase, 2015). Comparison of return of investment of the PV power plants in Germany, Spain and Morocco is in (Guaita-Pradas & Soucase, 2014a), due to the subsidy policy in Spain and low cost of electrical energy in Morocco it is actually Spain with the shortest return of investment, also called the internal rate of return.

MATERIALS AND METHODS

PVGIS software used for comparison of real and predicted data is available for free on the website: http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?lang=en&map=europe.

This website provides several options for calculations: PV estimation, monthly radiation, daily radiation and stand-alone estimation. This paper focuses on PV performance estimation given by PVGIS software and its deviation from real PV systems with same parameters. PVGIS software can give the prediction for the area of Europe, Asia, and Africa.

PVGIS software can generate a lot of useful information for potential investor given some necessary information about intended project such as installed peak PV power, used PV technology (the most common one is crystalline silicon), estimated losses, radiation database (there are 2 options, one based on ground measurement and other based on satellite data), inclination and orientation of PV system. This paper deals only with PV estimation option from above-mentioned website.

PVGIS software takes into the account losses of the PV system. Estimating losses due to the soiling, aging and degradation of materials are given in (Thevenard & Pelland, 2011). Estimating losses thanks to the shading are given in (Nguyen & Pearce, 2012). Accuracy of the old and new solar irradiance database available in the PVGIS software is discussed in (Huld et al., 2012).

PV systems from two sites were chosen for the comparison, one in Prague in the Czech Republic and one near Valencia in Spain. In both cases we calculate the electricity production by using PVGIS software and then this output is compared with actual production data measured in situ.

PV SYSTEM IN THE CZECH REPUBLIC

The first PV system is located in Prague in the Czech Republic. PV system in Prague is located on the campus of CULS university in the roof of Engineering faculty in the northwest part of Prague. It is facing the southeast. Installation of this free-standing polycrystalline PV system is showed on Fig. 1.

Figure 1. PV system in Prague.

It's installed peak power is 10 kWp, the inclination is 35° and its technology is crystalline silicon. This installation cost around 11,000 €s. The maintenance costs 12,960 czk per year or around 480 €s per year. All these parameters are showed on Fig. 2 along with interface of PVGIS online tool. Losses were set to 0% because it is a brand new PV installation, total losses were 11%. The position of this installation is 50°7′42′′ latitude and 14°22′26′′ longitude.

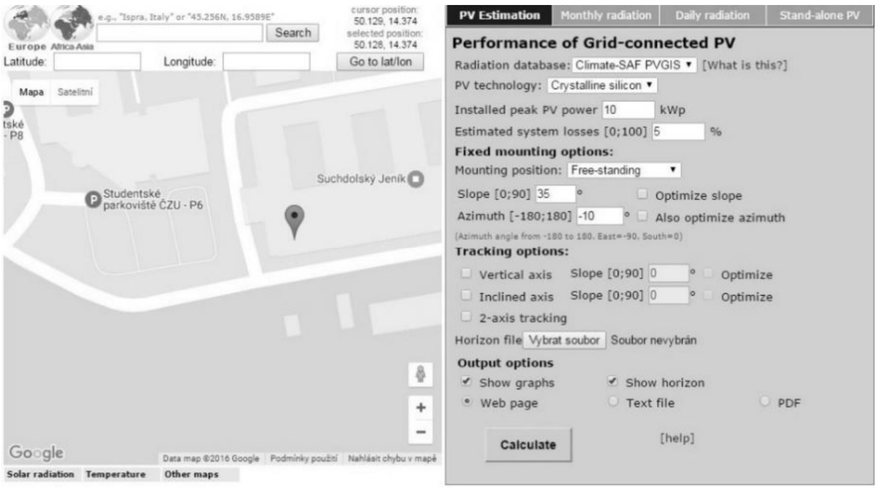

Figure 2. GUI of PVGIS with parameters for PV installation in Prague.

The output of PVGIS is in the form of pdf file or as a web page, it will generate the PV estimate in kWh per month, irradiation estimate in kWh sqm^{-1} per month and graph of horizon height in the summer and the winter solstice. The graph with the PV estimation is showed on Fig. 3. Total electricity production was estimated to 10,700 kWh. Currently, the price for 1 kWh generated by renewable resource on the market is same as for any other source, 3,4 czk for 1 kWh, that is around 13 € cents. According to this estimation, one year would yield the income of 1,445 €, the cost of the whole PV installation without the cost of maintenance would be pay off after less than 7 years and 8 months. However, data from the PV installation for the first year actually shows that electricity production was 11,881 kWh, therefore first year yields around 1,533 € of income and whole installation without the cost of maintenance will be payed off in 7 years and 3 months. If we consider the cost of the maintenance for 480 € per year (plus 3% inflation rate), than the whole PV system in Prague with the maintenance will be pay off in 10 years but that is only if the revenue will be each year the same (plus 3% of inflation rate).

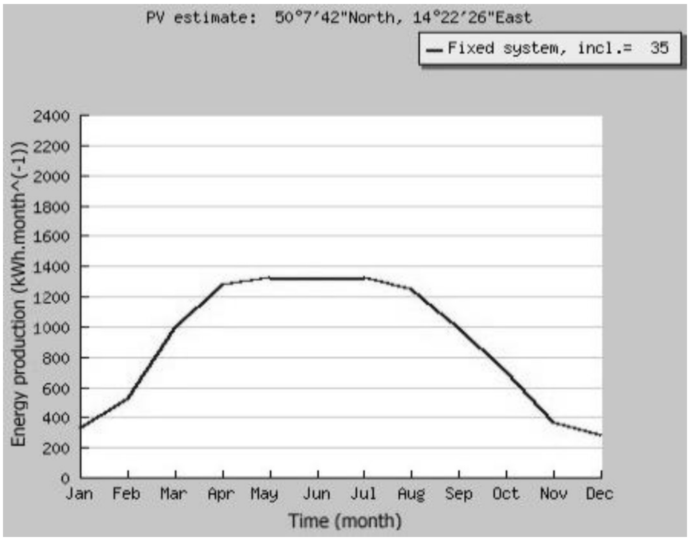

Figure 3. PV estimate for installation in Prague on the CULS campus.

The estimated irradiation is showed on Fig. 4. PVGIS can also calculate the horizon of the selected place but that is not important for this article. The irradiation is based on a database and currently an user of PVGIS can choose between older database which was based on a data collected in a ground stations between 1981–1990 or a new database that uses data from Meteosat satellites.

These calculations are compared with real data from PV installation in the northwest Prague in the CULS (Czech University of Life Sciences) campus.

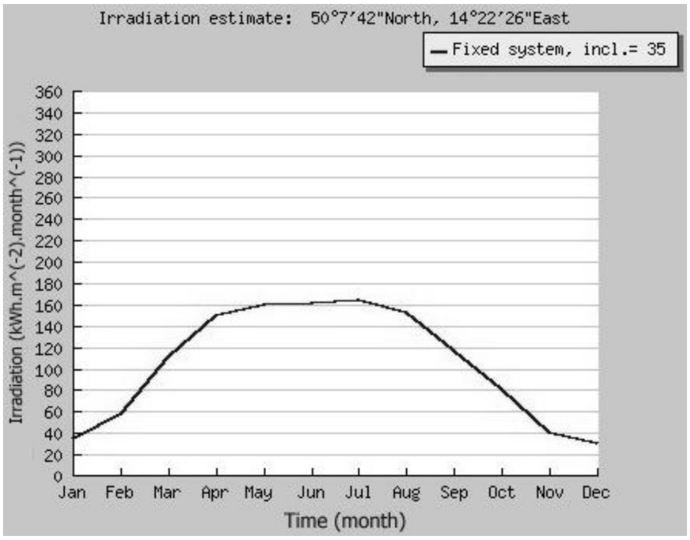

Figure 4. Irradiation estimate for Prague.

All predicted values by PVGIS in kWh per month are in the Table 1 along with the available real data.

Table 1. Generated electricity in kWh and estimate for each month

	Prague – estimated Em (kWh)	Prague – real Em (kWh)	Difference (%)
Jan.	343	358	-4.2
Feb.	551	559	-1.4
Marc.	1,030	873	17.9
Apr.	1,350	1,250	8
May	1,400	1,575	-11.1
Jun.	1,390	1,461	-4.9
Jul.	1,380	1,499	-8
Aug.	1,310	1,493	-12.3
Sep.	1,040	1,323	-21.4
Oct.	741	542	36,7
Nov.	382	554	-31
Dec.	294	394	-25.4
Aveg.	935	990	-5.6
Sum	11,200	11,881	-5.7

PV SYSTEM IN SPAIN

The second PV system is located in Spain in a moderate size city Ontinyent with 100,000 inhabitants located about 80 km south of Valencia. This PV system with polycrystalline technology was connected to grid in November 2011 when there was a governmental subsidy policy in Spain similar to that one in the Czech Republic where the owner of PV system has a guaranteed price for 1 kWh over a long time. In the case of Spain, the prime for the energy production was set at 0.28 € kWh^{-1} and this price will remain fixed for the next 25 years.

The PV system is facing directly towards the south and has the inclination of 35°. This PV system is divided into 4 parts across the whole city with total installed power of 255.3 kW. Because it was built earlier, the price for 1 installed Watt was around 1.8 € (Standard prices in 2011). The cost of this whole PV system was then about 459,540 €. One part of it has an 115.92 kW installed power and its located on the roof of Colegio Público Rafael Juan Vidal. The satellite picture of this place is on Fig. 5.

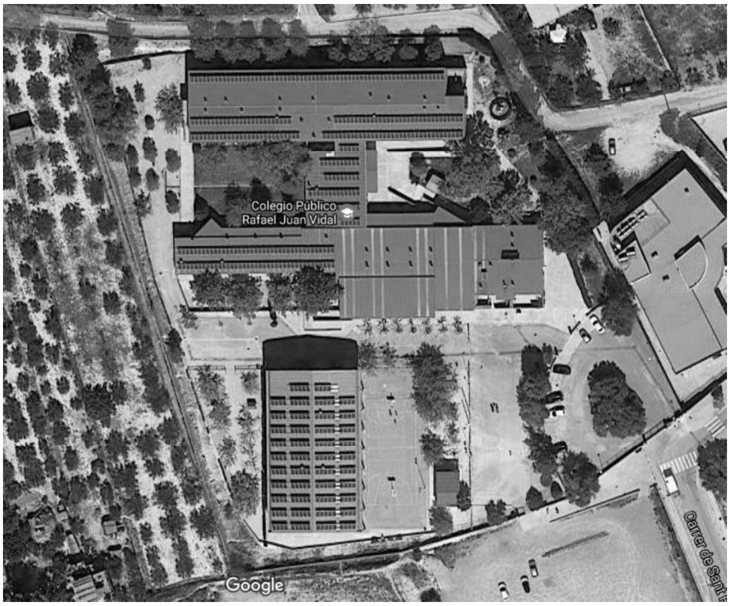

Figure 5. Picture of the PV system in Ontinyent from Google Maps.

Because the system was connected to the grid at the end of 2011 and the year 2017 is not over yet, all calculations are cumulative for five consecutive years from 2012 till 2016. In Table 2 is data from these five years along with estimate from PVGIS, the difference between the two and also losses that were set in PVGIS.

Table 2. Yearly yield of PV system in Ontinyent and estimate by PVGIS with losses

Year	Estimated Em (kWh)	Real Em (kWh)	Differ. (%)	Losses (%)
2012	392,000	392,542.02	-0.14	14.50
2013	392,000	392,731.00	-0.19	14.50
2014	388 000	388,363.00	-0.09	15.50
2015	381,000	380,902.00	0.03	17.00
2016	372,000	371,337.30	0.19	19.00

This PV system was built when the Spanish government was subsiding the renewables and so it has the guaranteed price of 0.28 € for 1 kWh for 25 years. The policy of Spanish government changed since then and the prefearibility of the investment into PV power plants after the change of the subsidy policy is discussed in (Guaita-Pradas & Soucase, 2014b). In last two months of 2011 when this PV system was operational, the revenue was 8,452 €. For each year the calculation assumes 3% inflation rate and also 9% of revenue will go for the insurance and the maintenance. The cost of the whole PV system was about 459,540 € and for two months of 2011 and five years between 2012–2016 the net revenue of this PV system was 513,357 € while according to the PVGIS it should be a little smaller at 512,896 €, the difference is less than 0.05%. So the PV system is Spain was already payed off in 4 years and 8 months. As can be seen from Table 2 PVGIS is quite good at predicting the revenue from a given PV power plant over whole year but not for each month which was the case of Prague. The difference for one month varied widely over the year in the case of Prague, between – 25% to + 37%. But in the case of Ontinyent in Spain, the estimate only varied less than 0.2%. In Table 3 there are some parameters for both PV system in Prague and Ontinyent.

Table 3. Production data related to both PV installations

PV installation	PV peak power (kW)	Energy produced (kWh year^{-1})	Energy production/ Peak Power (kWh kW^{-1})	Irradiation (kWh m^{-2})	Income/ kWh (€ kwh^{-1})	Payback time (months)
Prague	10	11,881	1,188.1	1,250	0.13	120
Ontinyent	255.3	331,337.3	1,297.84	2,010	0.28	56

RESULTS AND DISCUSSION

As can be seen from Table 3, the PV system in Ontinyent performs better than the PV system in Prague as well its return of investment is much shorter. This can be due to several factors. Mainly orientation of the panels and the geographical position and thus the irradiation received by the panels of the PV power plant are two main factors for the energy production. In Table 4 there are data from the site in Ontinyent about energy production and open data from AEMET about rainfall in Xativa, a site that it's closest to this city in this open access database for possible influence on the energy production.

Table 4. Rainfall in Xativa near Ontinyent and energy production 2012–2016 in Ontinyent

Year	Energy produced (kWh year^{-1})	Yearly difference (%)	Rainfall (mm)	Yearly difference (%)
2012	392,542.02	-	415.8	-
2013	392,731.00	+ 0.05	307.6	-26.03
2014	388,363.00	-1.11	199.2	-35.25
2015	380,902.00	-1.93	355.4	+ 43.96
2016	371,337.30	-2.52	515.8	+ 45.13

Firstly, Ontinyent is in a souther position than Prague, Pragues has a latitude of 50°7´ while Valencia has a latitude of 39°28´, the difference is over ten degress. Prague also has a typical central European climate, in 2016 Prague had 590 mm of rainfall which was on 91% of a longterm average (Český hydrometeorologický ústav, 2017). While Ontinyent is less than 50 km away from the Mediterranean Sea and thus it has a weather close to that of a coastal cities. Valencia and Ontinyent also has on average less rainfall during a year, there was 67 rainy days with 518 mm of rainfall in 2016 in Valencia while there was 68 rainy days with only 404 mm of rainfall in 2015 in Valencia (AEMET OpenData, 2017). Less precipitation with a southern position in turn means more average yearly sun irradiation as can be seen from Table 3. In Table 4 there is a sum of energy produced in a whole year for a period of time 2012–2016 in Ontinyent with data about rainfall in each year to see if the rainfall affects the production at this site. From 2013 onwards the production was dropping annually by 1–2% which is an average annually drop in the energy production for the PV panels thanks to aging or soiling of the panels. In this site, the PV panels are using polycrystalline technology which is less sensitive to the cloudy weather because these panels can easier absorpt the diffused solar radiation from clouds. Also, more rain occurs during winter months when the production is smaller than during summer months. Moreover, rain cleanes the panels from the dust and their production improves. The change in the rainfall doesn't affect the 1–2% drop in the production.

CONCLUSIONS

The PVGIS is good at predicting the revenue from a given PV power plant over whole year but not for each month which was the case of Prague. The difference for one month varied widely over the year in the case of Prague, between -37% to + 18%. But in the case of Ontinyent in Spain, the estimate only varied less than 0.2%.

The renewable energies are the main hope in substituting the current fossil based economy and their ecological impact is much lower than that of fossil energies. According to (Castro et al., 2013) the global electric power available from the solar energy in the 21st century can be around 2–4 TW while in the year 2013 there was only 0.008 TW of net average solar power production. Especially the countries with a lot of hours of sunshine during a year, like Spain, should be interested the most in the solar energy.

Both countries have a different conditions whenever it's a subsidy policy that supports the investments into the renewable energy sources or amount of irradiation received by a year in that country. However, in both cases, the PV power plant is actually profitable in a matter of few years.

The PVGIS can be used to produce estimate accurate enough for the investors who want to invest into PV power plants.

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