5TH CARPE CONFERENCE
23-25th October 2019, Valencia (Spain)
http://dx.doi.org/10.4995/CARPE2019.2019.10205

Assessing the increase of solar fields in Iberian Peninsula

Paula Bastida-Molina[1], David Alfonso-Solar[2], Carlos Vargas-Salgado[1], Lina Montuori[2]

[1]Department of Electrical Engineering, Universitat Politecnica de Valencia, Spain, [2]Department of Applied Thermodynamics, Universitat Politecnica de Valencia, Spain.

Abstract

*Spanish electrical generation has traditionally included high pollutant energy resources, like fuel or carbon. However, disturbing ever-increase in the average temperature of Planet Earth has led to a search for sustainability in the energy scenario. Therefore, Spanish electrical generation mix is prone to replace contaminant energy resources by non-contaminant, such renewables. Concretely, Spain is one of the countries with more solar peak annual hours. Nevertheless, having enough space to increase solar fields has been widely question. In this paper, an unrealistic scenario where all the annual Spanish consumption would be covered by photovoltaics is deeply analysed. Considering real electrical Spanish consumption data from 2017, required total quantity of solar panels has been quantified. Additionally, the study takes the hypothesis that all the panels should be placed on Spanish sunny desert zones for two main reasons. First, total solar peak annual hours there are higher than in other Spanish regions. Last, making there the installation would give use to previous wasted zones. Obtained results indicate that around 691 million of 330*W_p *solar panels would be required for this issue, taking up 3799* km^2*. This space means only a 0.77% of all Iberian Peninsula. These outcomes clearly show that there is suitable and enough space to increase solar fields in Iberian Peninsula.*

Keywords: *Photovoltaics, solar fields, space, increase, Iberian Peninsula.*

1. Introduction

Our Planet has been suffering a worrisome temperature growth for years, caused mainly by the enormous amount of carbon dioxide emitted to the atmosphere. If average temperature of Planet Earth continues increasing, the consequences for coming generations will be devastating (Ziegler, Morelli, & Fawibe, 2019). Preventing this situation has become one of the most important problems for almost every country. Therefore, a wide range of preventing climate change policies are being develop all over the world.

Regarding Spain, electrical generation has traditionally used high polluting sources, like fuel or carbon, or low polluting sources like natural gas. In 2016, electricity generation mix was formed by a 7% of fuel sources, 18% of carbon sources and 17% of natural gas sources. Non-polluting electricity generation sources (nuclear and renewables) represented 57% of all the generation mix. However, renewables had only a weight of 25% of the total mix ("International Energy Agency," 2018). The necessity of reducing CO_2 emissions together with the recent Spanish policy measures to promote renewable energies have boosted the introduction of higher levels of renewable sources for electricity generation, with the corresponding reduction of high polluting sources ("Red Eléctrica de España | Series estadísticas nacionales," 2017).

Furthermore, Spain is one of the countries with more solar peak annual hours, so that photovoltaic solar energy could be the most suitable renewable energy to produce large quantities of clean energy (Saiz Jiménez, Hurtado Pérez, & Saiz Melia, 2017). The Spanish regions with the highest number of solar peak annual hours are placed in the south-east of Iberian Peninsula, where vast and wasted desert zones are placed. Hence, using these areas to create big solar photovoltaic fields seems a great solution to generate clean energy.

The aim of this research is to finally calculate if Spain has enough and suitable space to increase solar fields. To this issue, an unrealistic scenario where all the 2017 annual electrical Spanish consumption is covered by solar photovoltaic energy has been studied. Canary Islands and Baleares Islands are not consider in this work, so that only Iberian Peninsula is taken into account.

2. Design process

2.1. Solar peak annual hours

The total quantity of solar photovoltaic energy necessary to cover all the Iberian Peninsula electrical consumption should be calculated considering that the solar fields will be placed in the Spanish regions with highest solar peak annual hours. These communities are the ones located in the south-east of Iberian Peninsula, like Murcia, Almería, Jaén, Granada o

Albacete. It won’t be optimal to install them in the Vasc Country or Navarra, for instance (AEMET, 2019).

Moreover, it is necessary to design the installation for the most unfavorable month, being it the one with the highest relation between electrical demand and solar photovoltaic generation. Since the installation will be placed in Iberian Peninsula, this month will be a winter month because it is in this season when solar radiation is lower. For this situation, most suitable annual tilt of solar panels is 60º, so that winter solar gain is facilitated (Bastida Molina, 2016).

Hence, using free software tool PVGIS, it is possible to obtain monthly solar radiation for a 60º tilt for every south-east region of Iberian Peninsula measured in solar peak hours (SPH). With these data, average monthly south-east Spanish regions radiation is calculated.

Table 1. Iberian Peninsula monthly SPH.

Month	Murcia	Almería	Jaén	Granada	Albacete	Average
January	154,38	158,41	138,88	149,11	128,34	145,82
February	151,20	162,12	151,20	153,72	140,28	151,70
March	184,76	196,54	180,42	184,45	171,74	183,58
April	161,10	173,10	155,70	156,60	155,40	160,38
May	161,51	165,23	159,65	158,10	155,62	160,02
June	157,20	156,60	159,60	158,70	155,70	157,56
July	170,50	167,71	176,08	174,22	175,15	172,73
August	179,80	182,59	189,41	187,55	181,97	184,26
September	169,80	179,70	177,90	178,80	170,40	175,32
October	173,60	183,21	178,56	185,07	165,85	177,26
November	149,10	157,80	144,00	152,10	132,90	147,18
December	140,43	154,69	136,40	149,42	124,00	140,99

Source: PVGIS (2019).

2.2. Electrical demand

The present work is referred to 2017. Monthly real electrical demand of Iberian Peninsula of this year is obtained from (“Red Eléctrica de España | Series estadísticas nacionales,” 2017).

Table 2. Monthly electrical demand of Iberian Peninsula (GWh)

Month	Electrical demand
January	23.078
February	19.959
March	21.087
April	18.963
May	20.205
June	21.680
July	22.413
August	21.769
September	20.145
October	20.161
November	20.893
December	22.151

Source: Red Eléctrica Española (2017)

2.3. Most unfavorable month choice

Once average monthly SPH (Table 1) and Electrical Demand in 2017 (Table 2) of Iberian Peninsula are determine, it is possible to stablish what is the most unfavorable month in terms of energy. This month will be the one with highest relation between electrical demand and solar photovoltaic generation (Bastida Molina, 2016). Average monthly radiation is expressed in SPH, which is equivalent to kWh/m^2. For having a coherent relation between this parameter and monthly electrical demand, this last term should be expressed in kWh, as Table 3 indicates.

Table 3. Most unfavorable month choice.

Month	SPH	Electrical demand (kWh)	Relation
January	145,82	23.078.000.000	158.259.271,45

Source: PVGIS (2018), Red Eléctrica Española (2017) and own elaboration.

Finally, most unfavorable month is January, as Table 3 shows, so that the installation will be design for this month. On the one, it is verify that this month takes places in winter, as previous hypothesis has stablished. On the other hand, the solar photovoltaic installation needs to be design for this month, since it is the one with highest and most unsuitable energy conditions.

3. Number of solar photovoltaic panels

Considering the month of designing (the most unfavorable in terms of energy), the electrical demand and the SPH of this month, the total number of solar panels to install could be calculated and therefore the total solar photovoltaic power. Designing parameters are summarized in Table 3.

The total initial power of the installation (P_i) can be expressed by equation (1), where E_d represents monthly electrical demand of January and SPH indicates the quantity of solar peak hours of the same month.

$$P_i = \frac{E_d}{SPH} \tag{1}$$

This factor needs to be increased by two more terms (Bastida Molina, Saiz Jiménez, Molina Palomares, & Álvarez Valenzuela, 2017), like equation (2) shows. Hence, final total power of the installation (P_f) can be determine.

On the one hand, term k_1 encompasses all the global losses that could occur in the installation and that are all different in nature. Some of these losses could be the reduction of the installation efficiency due to the accumulated dirt on the panels, drops in voltage in wires, differences among fabrication tolerances of the equips, differences among the operation of the panels…(Lu & Zhao, 2019). A wide span of studies claim that obtaining the exact value of this term turns out to be certainly complicated, since it does not follow a mathematical method and the variability of all the losses that it includes is very diverse (Bastida Molina, 2016; Bastida Molina, Saiz Jiménez, et al., 2017; Bastida Molina, Saiz Jiménez, & Molina Palomares, 2017). These works have quantified this term in 1.2, meaning that initial power of the solar field is increased in a 20%.

On the other hand, term k_2 includes the losses of solar panels due to the test of time. This information should be given by the manufacturer. As standard procedure, panels suffer a lineal decrease of their efficiency due to the test of time of 20% during the firsts 25 years, so that k_2 has a value of 1.2. ("Garantía lineal potencia Módulos Fotovoltaicos Estándar ATERSA," 2013).

$$P_f = P_i \cdot k_1 \cdot k_2 \tag{2}$$

Once total final power of the installation is obtain, it is possible to calculate the quantity of panels (N_p) of the solar field in question. To this issue, it is considered that an individual panel has a nominal power of 330 W_p (Saiz Jiménez et al., 2017). Equation (3) is used to this aim, where total final power of the installation (P_f) and the nominal power of an individual panel (P_p) are considered.

$$N_p = \frac{P_f}{P_p} \quad (3)$$

Applying this methodology, it has been possible to know that the solar field in question would ideally be formed by 691million of panels with 228 GW of total power, like Table 4 indicates.

Table 4. Number of panels and total power of the solar field in question.

Number of pannels (million)	Total power (GW)
691	228

Source: Own elaboration.

4. Area of the total installation

The total area of the studied solar photovoltaic installation depends on the horizontal area of the solar panel (A_h) and the distance to dispose among rows of panels to prevent them from shading (d).

Standard dimensions of 330 Wp solar photovoltaic panels are about 1960·40·990· mm (height · width ·length). Moreover, its tilt is also defined (60º), as the most unfavorable month in terms of energy is January. Hence, considering both factors, horizontal area of solar photovoltaic panels could be obtained with equation (4), where l indicates length dimension, h high dimension and t represents the tilt.

$$A_h = l \cdot h \cdot cos(t) \quad (4)$$

This area should also be increased by the area that needs to be provided among rows of panels to prevent them from shadowing (Oh & Park, 2018). The methodology followed to determine the appropriate distance lies in multiplying relative height of the panels by a factor. This factor depends on the latitude of location of the installation, that acquires a value of 40º for Iberian Penninsula. Equation (5) is used to calculate the distance among rows of panels, where d indicates distance, lat latitude and h height.

$$d = \frac{1}{tg(61 - lat)} \cdot h \quad (5)$$

Therefore, the required area among rows of panels to prevent shading (A_s) could be obtain by equation (6), where distance (d) and length of the panel are considered (l).

$$A_s = l \cdot d \tag{6}$$

Finally, considering these two areas, the total area that takes up one individual panel (A_p) could be obtain by equation (7). Knowing this value and the total number of solar photovoltaic panels that formed the installation, the total area (A_t) that the solar field needs is finally determine by equation (8).

$$A_p = A_h + A_s \tag{7}$$

$$A_t = A_p \cdot N_p \tag{8}$$

Hence, it has been possible to determine the total area that the solar photovoltaic field required to cover all the electrical demand of Iberian Peninsula would take up: 3799 km^2.

Table 5. Total area of the solar photovoltaic field in question (km^2).

Total area
3799

Source: Own elaboration.

5. Conclusions

The uncontrolled quantity of CO_2 emissions that have been emitted to the atmosphere for years have led to a disturbing temperature raise of Planet Earth. A wide span of climate change policies are being developed in almost every country, so that most polluting activities tend to disappear.

Regarding Spain, its electrical generation mix is suffering a transformation, since renewable energies are being introduced. Therefore, with this paper it has been possible to verify that the high number of annual SPH of Spanish Iberian Peninsula (1957) make solar photovoltaic energy an ideal clean energy to generate electricity in this country. Moreover, the unrealistic scenario of covering all the electrical consumption that was really demanded in 2017 with solar photovoltaic energy has been analyzed. Results have proved that the required solar field would take up an area of 3799 km^2, which only represents a 0.77% of all Iberian Peninsula. South-east regions of Iberian Peninsula are the most suitable ones to place the installation for different reasons. First, these communities are the ones with highest SPH of the Peninsula. Last, large desert zones with no use are located in south-east regions, so installing the solar field there would give use to a previous wasted zone.

To sum up, Iberian Peninsula is likely to increase the percentage of solar photovoltaic energy in the electricity generation mix since it has suitable and enough space to achieve it.

Acknowledgment

This work was supported in part by the regional public administration of Valencia under the grant ACIF/2018/106.

References

AEMET. (2019). *Atlas de radiación solar en España*. Retrieved from http://www.aemet.es/es/serviciosclimaticos/datosclimatologicos/atlas_radiacion_solar

Bastida Molina, P. (2016). *Estudio de distintas alternativas fotovoltaicas para alimentación de una instalación*. Retrieved from https://riunet.upv.es/handle/10251/74582

Bastida Molina, P., Saiz Jiménez, J. Á., Molina Palomares, M. P., & Álvarez Valenzuela, B. (2017). Instalaciones solares fotovoltaicas de autoconsumo para pequeñas instalaciones. Aplicación a una nave industrial. *3C Tecnología*, 1–14. https://doi.org/http://dx.doi.org/10.17993/3ctecno.2017.v6n1e21.1-14

Bastida Molina, P., Saiz Jiménez, J. A., & Molina Palomares, P. (2017). *Pequeñas instalaciones alimentadas por sistemas solares de autoconsumo Aplicación a un caso real*.

Garantía lineal potencia Módulos Fotovoltaicos Estándar ATERSA. (2013). Retrieved December 26, 2018, from http://www.atersa.com/Common/pdf/atersa/garantias/Garantias-Modulos-Nov13.pdf

International Energy Agency. (2018). Retrieved June 28, 2019, from https://www.iea.org/statistics/electricity/

Lu, H., & Zhao, W. (2019). CFD prediction of dust pollution and impact on an isolated ground-mounted solar photovoltaic system. *Renewable Energy*, *131*, 829–840. https://doi.org/10.1016/J.RENENE.2018.07.112

Oh, M., & Park, H.-D. (2018). A new algorithm using a pyramid dataset for calculating shadowing in solar potential mapping. *Renewable Energy*, *126*, 465–474. https://doi.org/10.1016/J.RENENE.2018.03.068

Red Eléctrica de España | Series estadísticas nacionales. (2017). Retrieved December 26, 2018, from Red Eléctrica Española website: https://www.ree.es/es/estadisticas-del-sistema-electrico-espanol/series-estadisticas/series-estadisticas-nacionales

Saiz Jiménez, J. Á.;, Hurtado Pérez, E., & Saiz Melia, Á. (2017). "Energía solar fotovoltaica y consumo eléctrico en España." Retrieved December 26, 2018, from Valencia Plaza website: https://valenciaplaza.com/energia-solar-fotovoltaica-y-consumo-electrico-en-espana

Ziegler, C., Morelli, V., & Fawibe, O. (2019). Climate Change and Underserved Communities. *Physician Assistant Clinics*, *4*(1), 203–216. https://doi.org/10.1016/j.cpha.2018.08.008