Performance of photovoltaic system of the UTFPR - Analysis of four years of operation

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Abstract: The aim of this paper is to show the performance of the grid-connected PV system, located in UTFPR Curitiba. In the four years of analysis, the energy generated and the solar radiation were locally monitored and used to calculate the performance parameters, such as Final Yield, Performance Ratio and Capacity Factor. The results show that the dirty accumulation on the PV panel has been an important factor to reduce the photovoltaic system performance.

Energy Systems Pos Graduation Program (PPGSE)[1]
Civil Engineering Pos Graduation Program (PPGEC)[2]

Introduction

The UTFPR' s PV system (Curitiba, Brazil, latitude: 25°43' S, longitude: 49°25' W), became operational in December 2011, and since then operates continuously. It is formed by a string with ten modules of 210 W, which was built with polycrystalline silicon cells, connected to a single string inverter input of 2000 W. The PV panel has about 15º tilt angle and 22º west from due north [1].
This paper aims to analyses the photovoltaic system in four years of operation in terms of productivity parameters, highlighting the factors that interfere in the performance of a grid-connected PV system.

Methods

This paper focuses on UTFPR' s PV system performance parameters. Final Yield, Performance Ratio and Capacity Factor, were analyzed in the period from 2012 to 2015, so it represents four years of operation of the grid-connected PV system. The local solar irradiation in the horizontal plane is obtained from the Brazilian Institute of Meteorology (INMET) [2] as well as Meteorological System of Paraná (SIMEPAR) [3].
This information is the entrance for the software Radiasol [4], which provides the solar irradiation to different inclinations. The energy generation is recorded by the PVP 2000 inverter, which is online monitored through the internet. This analysis involves the limiting factors for photovoltaic systems, as well as suggests ways to improve its operation performance.

1 Performance of PV Systems
The performance analysis of grid-connected PV system is based in electricity generated during these four years of operation and also irradiation values that were incident on the surface of the PV panel. Then the electricity generated and the solar radiation were locally monitored, therefore the performance parameters were calculated, such as Final Yield, Performance Ratio and Capacity Factor.

2 Generated energy
Analyzing the PV system operation in the years 2012 (2.44MWh), 2013 (2.21MWh), 2014 (2.42MWh) and 2015 (≈2.3MWh), was observed a total generation of ≈9.3MWh in this time. The electricity generation was proportional to solar radiation reflected into PV panel, whereas in the summer months (higher solar radiation) there is higher generation than the winter months (lower solar radiation).

3 Irradiation on PV panel
The irradiation values on PV panel were used as basis to calculate some of the performance parameters of the PV system. These values were acquired through National Meteorology Institute (INMET) database for the A807 station, located in Curitiba [2]. Besides INMET database, the SIMEPAR Technological Institute, other metrological database, was consulted during to period from 07/19/2014 to 10/08/2014, when the INMET site was unavailable to data collection, caused by technical problems. Although the INMET and SIMEPAR pyranometers are installed in horizontal position, it is necessary to use the RADIASOL program to determine the real irradiation reflected on PV panel. The RADIASOL is available for the Federal University of Rio Grande do Sul [4], and it allows to identify the irradiation values to any surface (different azimuth angles and tilt angle related to North) through insertion of the irradiation values on horizontal surface. Having adjusted the tilt angle to 15° and the azimuth angle to 22° west.

4 Performance parameters
Final Yield, Reference Yield, Performance Ratio and Capacity Factor are going to be described [5], [6].
Final Yield (YF) is defined by the daily, monthly or annual net AC energy output of the system (E) divided by the rated or nominal power of the PV array at STC. Equation (1) represents this parameter.

$$Y_F = \frac{E}{P_{PV}}\left[\frac{kWh}{kWp}\right] \quad (1)$$

Performance ratio (PR) quantifies how much of the available solar energy is converted into electricity. It indicates the overall effect of losses, caused mainly by the factors that influences on productivity, such as environmental factors (temperature, wind speed, soiling, partial shading). Moreover, performance ratio permits to compare the PV systems independent of location, nominal rated power capacity, orientation and tilt angle. Equation (2) is the calculation process to obtain PR, where H_T is total in-plan solar irradiation (kWh/m².year).

$$PR = \frac{Y_F}{H_T}[\%] \quad (2)$$

To conclude, the capacity factor is defined as the ratio of the actual annual energy output (E) to the amount of the energy that the PV system would generate, if it operated at full rated power for 24 hours per day for a year.

$$CF = \frac{E}{P_{PV}.8760}[\%] \quad (3)$$

Results

1 Generated energy

Analyzing the PV system operation in the years 2012, 2013, 2014 and was observed a total generation of 9,2 MWh in this time. The electricity generation was proportional to solar radiation reflected into PV panel, whereas in the summer months (higher solar radiation) there is higher generation than the winter months (lower solar radiation).
Figure 1 shows the electricity generated in each operation month of PV system of the UTFPR.

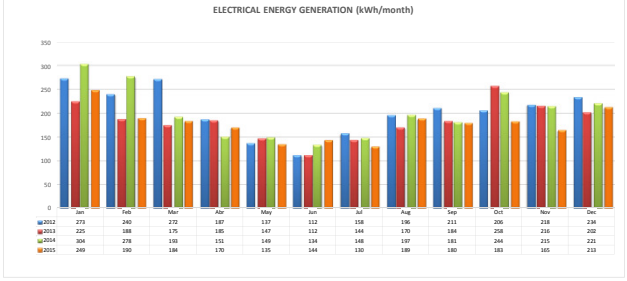

Figure 1 – Electricity generation (kWh/month) for the years 2012, 2013, 2014 and 2015.
Source: The authors

2 Irradiation on PV panel

The values of the irradiation on PV panel were acquired through National Meteorology Institute (INMET) database for the A807 station, located in Curitiba.
The irradiations' values from 2012 to 2015 are showed in the Figure 2.

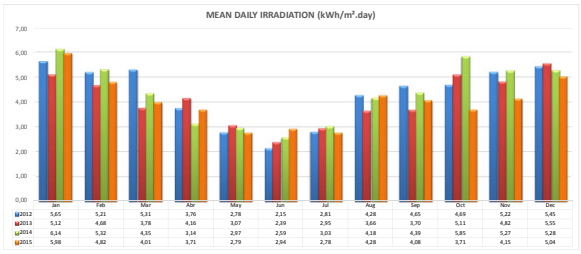

Figure 2 – Mean daily irradiation on horizontal surface provided by INMET (kWh/m².day).
Source: The authors.

The Figure 3 shows the initial software interface that allows you to choose parameters according to the specific place where the PV panel is installed.

Figure 3 – RADIASOL initial software interface.
Source: The authors.

Having adjusted the tilt angle to 15° and the azimuth angle to 22° west, the graphic presented at Figure 4 and the irradiation values incident on PV panel surface are presented in the Figure 5.

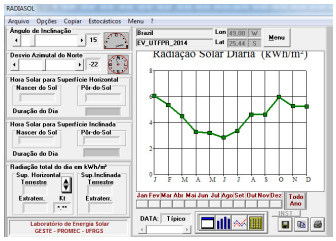

Figure 4 – RADIASOL interface showing the mean irradiation graphic during the year on the PV panel.
Source: The authors.

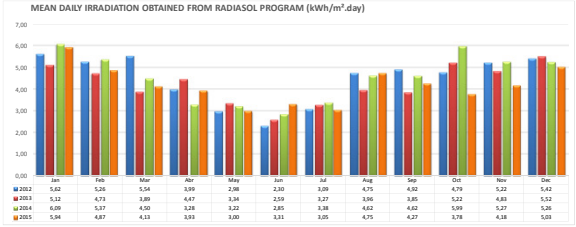

Figure 5 – Mean daily irradiation on GO's PV panel surface obtained from RADIASOL software (kWh/m².day).
Source: The authors.

Conclusions

The values of the Final Yield obtained in 2012, 2013, 2014 and 2015 were 1164kWh/kWp, 1050kWh/kWp,1150kWh/kWp and ≈1100kWh/kWp respectively. The values of the Performance Ratio in 2012 , 2013, 2014 and 2015 were 71.3%, 68.2%, 69.7% and ≈70% respectively. Finally, the values of the Capacity Factor in 2012, 2013, 2014 and 2015 were 13.25%, 12%, 13.16% and ≈13% respectively.
It was observed during operation of the UTFPR' s PV system a gradual reduction in their performance, which was reversed to each one of the two cleanings performed on the panel, one on September 2013 and another on August 2015. Small adopted tilt angle (15 degrees), making it difficult to self-cleaning, moreover the photovoltaic system is in an avenue with high traffic of cars and buses in the downtown, causing a dirt accumulation higher than expected, as consequently, this factor, the dirt has been identified as relevant at reducing the PV array performance.

References

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