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 PV system (Curitiba, Brazil, latitude: 2° 20’ 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 200 W. The PV panel has an 15° tilt angle and 22° west from due north.[5]

This paper aims to analyse the photovoltaic system in four years of operation in terms of productivity parameters, highlighting the factors that influence 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 assigned in the period from 2012 to 2015, as it represents four years of operation of the grid-connected PV system.

The local solar irradiation in the horizontal plane was obtained from the Brazilian Institute of Meteorology (INMET) [2], as well as the solar irradiation at flat panel from the SIMEPAR [3]. This information is the entrance for the software RadiaSol [4], which provides the solar irradiation to different inclinations. The solar irradiation was generated 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 on 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 and used to calculate the performance parameters, such as Final Yield, Performance Ratio and Capacity Factor.

2. Generated energy
Analyzing the PV system operation in the years 2012 (4,44MWh), 2013 (2,21MWh), 2014 (2,42MWh) and 2015 (0,9MWh), a total generation of 9,2 MWh has been recorded in this four years period.

3. Irradiation on PV panel
The irradiation values on PV panel were used as input to calculate some of the performance parameters of the PV system. The final yield was converted into electricity generated in the system, and using the relation value proportional to solar radiation reflected into PV panel, whereas the different months (higher solar radiation) has a higher generation than the winter months (lower solar radiation).

4. Performance parameters
Final Yield (FY), Performance Ratio (PR), and Capacity Factor (CF) are to be described [5].

Final Yield (FY) is defined by the daily, monthly or annual net AC energy output of the system (in kWh) divided by the rated or nominal power of the PV array at STC. Equation (1) represents this parameter.

\[ Y_F = \frac{E_{DC}}{P_{DC}} \]  

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 influence on productively, such as environmental factors (temperature, wind speed, solar panel shading). Moreover, the performance ratio permits to compare the PV systems independently of location, nominal rated power, orientation and tilt angle. Equation (3) is the calculation process to obtain PR, where $H_0$ is total solar irradiation on horizontal plane (kWh/year).

\[ PR = \frac{Y_F}{H_0} \]  

To calculate, the capacity factor is defined as the ratio of the actual annual energy output ($E_{AC}$): the amount of the energy that the PV system would generate, if operated at full-rated power for 24 hours per day for a year.

\[ CF = \frac{E_{AC}}{P_{AC}} \]  

Results
1. Generated energy
Analyzing the PV system operation in the years 2012, 2013 and 2014 and was observed a total generation of 8,12 MWh in this period. The electricity generation was proportional to solar radiation reflected into PV panel, whereas in the summer months (higher solar radiation) has a higher generation than the winter months (lower solar radiation).

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

Conclusions
The values of the Final Yield obtained in 2012, 2013, 2014 and 2015 were 1,61 MWh/yr, 1,00 MWh/yr, 1,00 MWh/yr and 1,00 MWh/yr 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%, 69.7% and 69.7% respectively. The values of the Performance Ratio in 2012, 2013, 2014 and 2015 were 71.3%, 68.2%, 69.7% and 70% respectively. The values of the Capacity Factor in 2012, 2013, 2014 and 2015 were 13.25%, 12%, 69.7% and 69.7% respectively.

It was observed that the PV system operates continuously. The efficiency of the PV system is in an avenue with high traffic of cars and buses in the daytime, causing a self-accumulation higher than expected, as consequence, the system has been identified as being one of the PV array performance.

References