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A N I N T E R N A T I O N A L J O U R N A L

Determination of the Ideal Time for Cleaning of Photovoltaic Panels Aiming at Better Productivity - Case Study of the Implanted Grid-Connected Photovoltaic System at the Federal University of Technology of Paraná

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ABSTRACT

Considering the development of new technologies in the electricity generation sector, such as solar photovoltaic energy, some studies are made necessary to obtain the best performance of these systems. This generation model consists of modules, which are exposed to adverse climatic conditions, they receive direct influence of the dirt, according to the environment from which they were installed, which directly influences the performance of the system since, due to the disposal of waste on the module, a smaller portion of the solar radiation can reach the photovoltaic cell effectively. The objective of this work is to determine the ideal time for cleaning photovoltaic panels, aiming at high system productivity, having as object of study the photovoltaic panels of the Federal University of Technology - Paraná (UTFPR) Campus Curitiba, installed in the Green Office (GO) and at Neoville´s headquarters. Within this objective, it was necessary to verify its merit indexes, parameters used to compare grid-connected photovoltaic systems. The study shows the importance of frequent cleaning of panels, especially when they are installed in urban areas and close to high traffic access roads.

Keywords: Photovoltaic Systems. Photovoltaic Solar Energy. Dirtiness. Performance Parameters.

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INTRODUCTION

The demands for using renewable energy sources has increased significantly in Brazil, among them solar photovoltaic energy which has a huge potential to be explored and presents low environmental impact.

The country has shown an expressive growth in the last years in the utilization of solar energy, and it is estimated that Brazil will reach 7 GW in photovoltaic capacity until 2024, which should represent 3.4% of the installed capacity in the Brazilian electrical matrix [1]. Currently, this source is responsible for only 0.02% of installed capacity in the country [2].

Brazil presents high values of solar radiation practically throughout its territory [3]. The horizontal global irradiation map is presented in Figure 1.

Considering the state of Paraná, it shows expressive irradiation values, which can be compared with best potentials found in Europe. Comparing its Total Annual Average Estimated Productivity with Europe, it can be seen that the average of Paraná is 58.75% higher than Germany, 13.48% higher than Italy, 1.97% higher than Spain, 31.28% higher than France, 60.46% higher than Belgium and 71.19% higher than the United Kingdom. Those percentages represent the surplus quantity of the Total Annual Average of electrical energy that a Grid-Connected Photovoltaic System (GCPVS) can generate in Paraná compared to each of those countries [4].

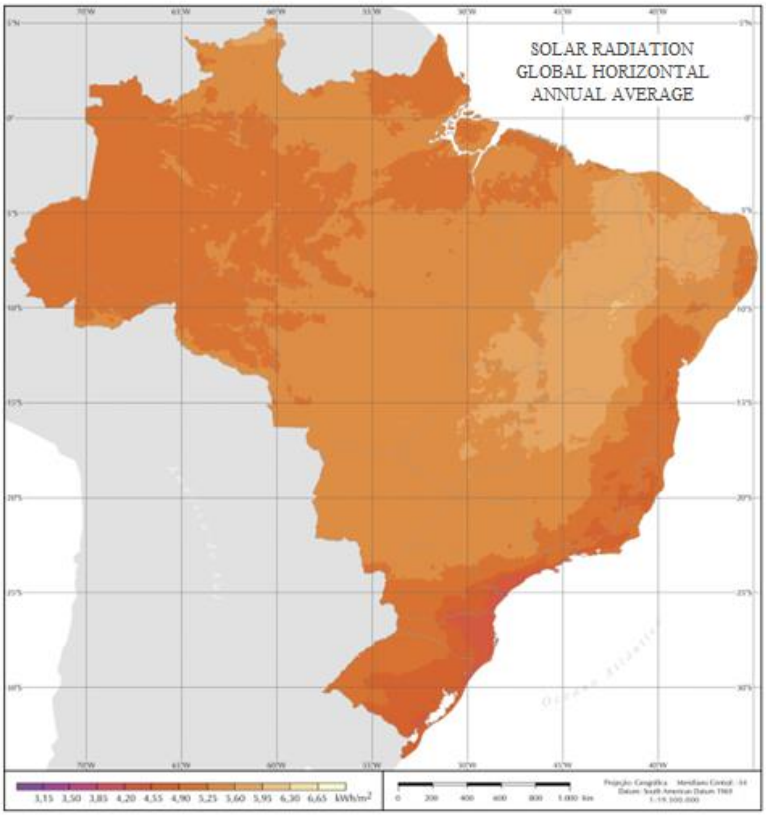


Figure 1: Map of global horizontal solar daily annual average in Brazil [3].

With all that growth of photovoltaic solar energy foreseen in Brazil, which should also occur in Paraná, given the great potential found in the state, a question arises, the preventive maintenance aiming always at a high performance of these systems, being one of them the cleaning of the modules to maintain the efficiency in the conversion of solar energy to electric energy through the photovoltaic effect [5]. That cleaning ensures a longer durability of photovoltaic panels, and also increases system productivity throughout the year by reducing blocking losses of solar radiation incident on the module due to the accumulation of dust and other agents. The accumulation of dirt in the photovoltaic panels may cause stains, fungi and corrosion in the modules, as well as reducing the amount of solar radiation that will directly affect the photovoltaic cells, reducing the productivity and the lifespan that is estimated between 25 and 30 years [6].

Based on the information obtained through this study, it is possible to identify the optimal time for cleaning the panels installed in the GO and at the UTFPR's Neoville headquarters, and then to propose parameters and guidelines for the development of a method that demonstrates which is the best time to do the maintenance on both photovoltaic panels.

MATERIAL AND METHODS

The GO is located at the Center Headquarters of UTFPR, Silva Jardim Avenue 807 in Curitiba, Paraná. This street has a large traffic of vehicles, so there is emission of large quantities of particles through the pollution and which stay suspended in the atmosphere, due to the combustion process of the engines, mainly those run by fossil fuel, and that are deposited in the surface of the photovoltaic modules, reducing the performance of the system. The GO panel is presented in Figure 2.

Figure 2: GO's Photovoltaic Panel [7].

This was the first GCPVS that was installed in Paraná in 2011, with uninterrupted operation since its implementation. The GO panel presents a slope of 15º to the north, with an azimuthal deflection of 22º to the west. There is a partial shading that occurs in the late afternoon, due to a building next to the GO. The power of this system is of 2.1 kWp, being constituted by 10 modules of 210 Wp [8].

The Neoville headquarters is also located in Curitiba, at Pedro Gusso Street 2671, in the Industrial City of Curitiba (CIC). This panel is located in a region with different weather conditions than those found in GO. Figure 3 shows the Neoville headquarters panel and its inverter.

Figure 3: Neoville headquarters' Photovoltaic Panel [9].

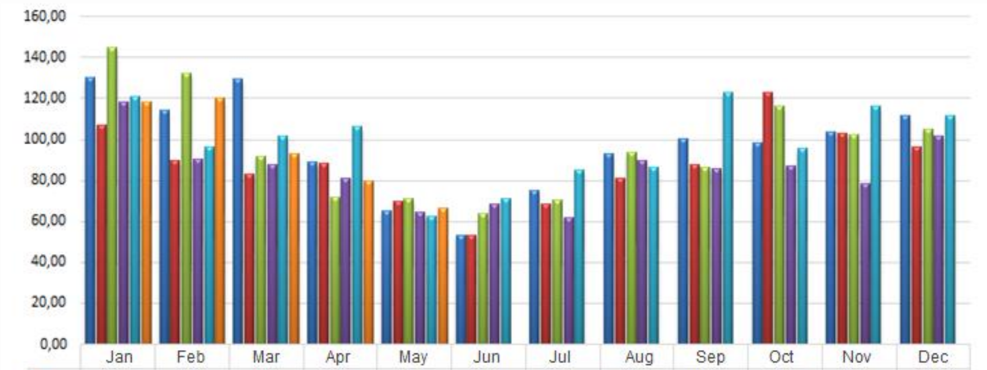
This panel was assembled in the ideal generation characteristics, with an inclination equal to Curitiba's latitude, which is 25º, and with orientation for the true north (or geographic), without azimuthal deflection. Its power is 10.2 kWp, being constituted of 34 modules of 300 Wp, made by two sets of 17 modules linked in series [10].

In order to evaluate and compare the performance of GCPVS, the merit indexes are used: Productivity (Yield), which is a proportion between the electric energy generated by the system related to the total power of GCPVS installed; Global Performance (Performance Ratio - PR), which sets a proportion between Productivity and Reference Productivity; Capacity Factor (CF) which is defined as the energy generated during a certain time interval and the value of the energy that could be generated if the system operated uninterruptedly. Normally, for comparison´s sake, these indexes are calculated over a period of one year. Graphics 1, 2 and 3 present respectively the merit indexes of Productivity, Performance Ratio and Capacity Factor obtained in the GO in the years 2012 to 2017.

In the GO three cleanings were carried out: the first one on August 31, 2013; the second one on September 26, 2015; and the third and most recent on September 1, 2016. The months highlighted in blue are the months in which they had the first cycle of operation, one month after the cleanings were carried out.

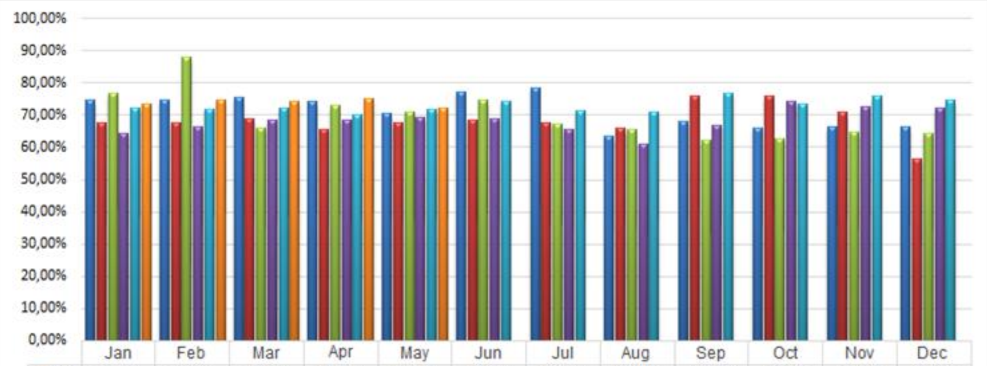
Having the GO's photovoltaic system as the first in the state of Paraná, this one has a great amount of data, so comparisons can be more effective, thus generating results with greater relevance.

After the cleaning in September/2016, it was possible to notice the change in merit indexes, where they all had an increase in their respective values, being the Yield from 86.19 kWh/kWp to 122.86 kWh/kWp, the Performance Ratio from 71.07% to 76.99% and the Capacity Factor from 11.58% to 17.06%.



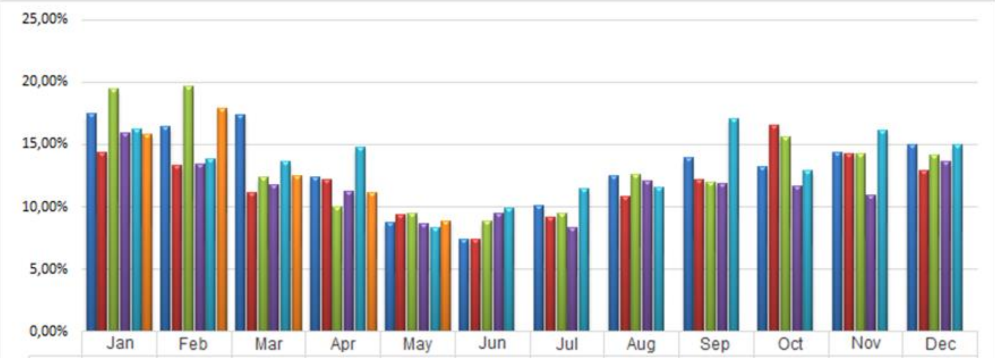
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	130,00	114,29	129,52	89,05	65,24	53,33	75,24	93,33	100,48	98,10	103,81	111,43
2013	107,14	89,52	83,33	88,10	70,00	53,33	68,57	80,95	87,62	122,86	102,86	96,19
2014	144,76	132,38	91,90	71,90	70,95	63,81	70,48	93,81	86,19	116,19	102,38	105,24
2015	118,57	90,48	87,62	80,95	64,29	68,57	61,90	90,00	85,71	87,14	78,57	101,43
2016	120,95	96,67	101,43	106,19	62,38	71,43	85,24	86,19	122,86	95,71	116,19	111,43
2017	118,10	120,00	92,86	80,00	66,19							

Graphic 1: Green Office's Yield (kWh/kWp) [11,12].



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	74,59%	74,89%	75,46%	74,32%	70,52%	77,29%	78,62%	63,40%	68,11%	66,13%	66,24%	66,33%
2013	67,54%	67,58%	69,12%	65,74%	67,57%	68,53%	67,64%	65,88%	75,84%	75,92%	70,93%	56,26%
2014	76,74%	87,99%	65,94%	73,01%	71,15%	74,68%	67,34%	65,47%	62,20%	62,57%	64,72%	64,55%
2015	64,41%	66,35%	68,39%	68,59%	69,22%	69,01%	65,45%	61,13%	66,91%	74,43%	72,51%	72,05%
2016	72,32%	71,84%	72,28%	70,34%	71,82%	74,34%	71,60%	71,07%	76,99%	73,57%	75,99%	74,59%
2017	73,50%	74,73%	74,38%	75,27%	72,16%							

Graphic 2: Green Office's Performance Ratio [11,12].

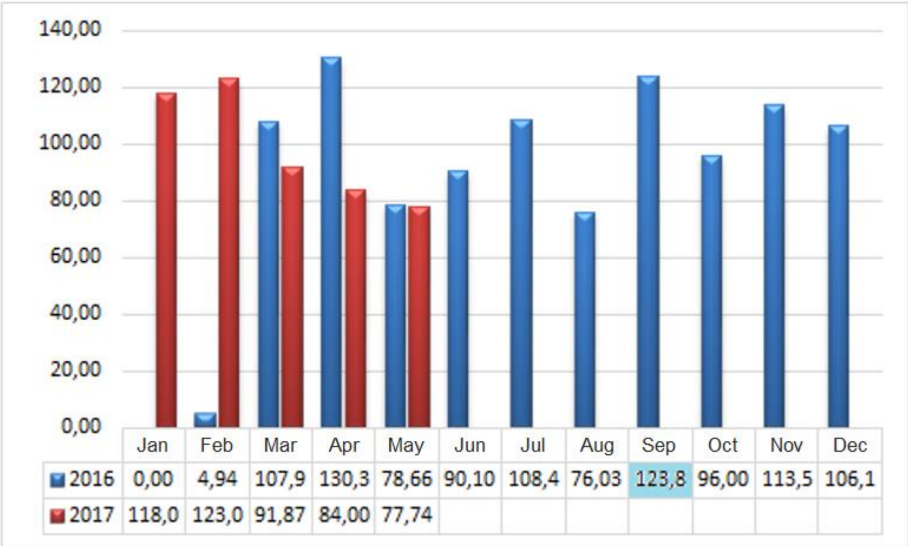


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	17,47%	16,42%	17,41%	12,37%	8,77%	7,41%	10,11%	12,54%	13,96%	13,18%	14,42%	14,98%
2013	14,40%	13,32%	11,20%	12,24%	9,41%	7,41%	9,22%	10,88%	12,17%	16,51%	14,29%	12,93%
2014	19,46%	19,70%	12,35%	9,99%	9,54%	8,86%	9,47%	12,61%	11,97%	15,62%	14,22%	14,14%
2015	15,94%	13,46%	11,78%	11,24%	8,64%	9,52%	8,32%	12,10%	11,90%	11,71%	10,91%	13,63%
2016	16,26%	13,89%	13,63%	14,75%	8,38%	9,92%	11,46%	11,58%	17,06%	12,86%	16,14%	14,98%
2017	15,87%	17,86%	12,48%	11,11%	8,90%							

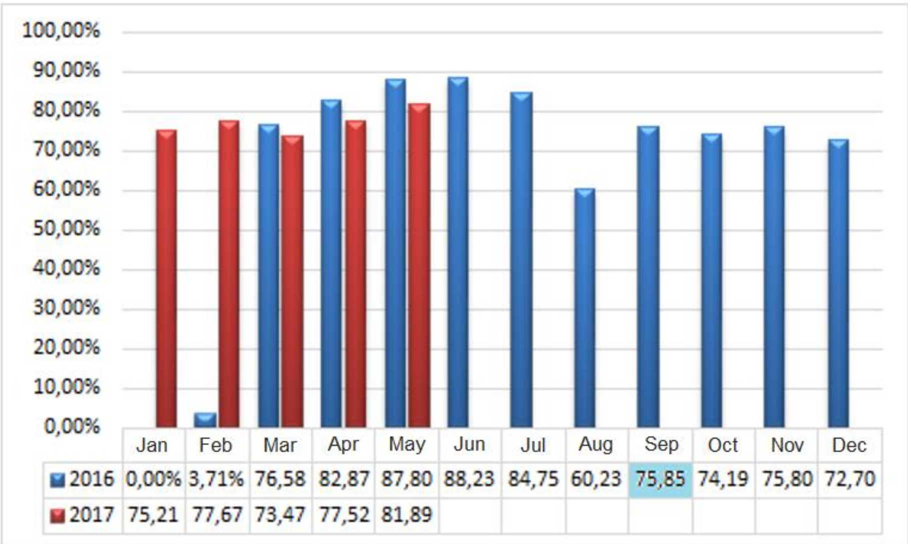
Graphic 3: Green Office's Capacity Factor [11,12].

The same process was carried out for the Neoville headquarters´s GCPVS, represented by Graphics 4, 5 and 6.

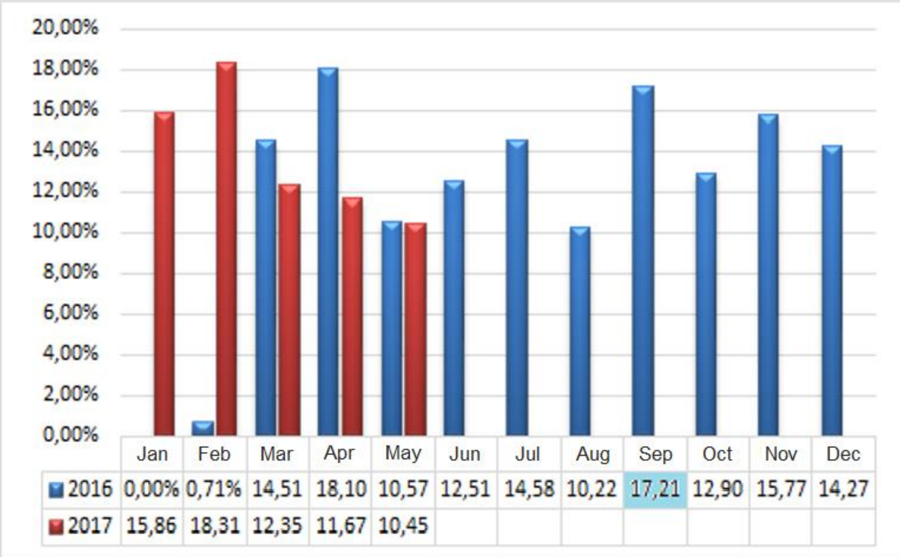
In the photovoltaic panel located at the Neoville, there was only one cleaning up to June 2017, which occurred on September 2, 2016. The month highlighted in blue is the month in which the first cycle took place, a month after the cleaning.



Graphic 4: Neoville headquarters' Yield (kWh/kWp) [12].



Graphic 5: Neoville headquarters' Performance Ratio [12].



Graphic 6: Neoville headquarters' Capacity Factor [12].

By observing the merit indexes close to the date of its cleaning (09/02/2016), it is possible to notice that there was a significant increase in these indexes, highlighting the Yield, which increased from 108.45 kWh/kWp to 123.88 kWh/kWp and Capacity Factor from 14.58% to 17.21%. However, the Performance Ratio decreased in proportion to the previous months, disregarding the month of August, which was atypical, since there were shutdowns on the inverter during some moments of the month, and that impacted on the measured values.

Since the Neoville photovoltaic panel was recently deployed, (a year of operation in February 2017), data acquisition is still under development.

RESULTS AND DISCUSSION

When analyzing the data obtained in the GO, the following averages were found: 70.83% on Performance Ratio; 12.96% on Capacity Factor; and 1111.24 kWh/kWh on Annual Yield.

In order to determine the optimal time for the achievement cleaning time of the GO photovoltaic panels, it was established as a standard that the system would operate regularly with a performance ratio of at least 70%.

If all the months when there was a performance ratio lower than 70% were changed so as to have at least 70%, the new average would be 72.46%. In this way, it was verified that the rate's decay over the years, in the first moment was seven months, in the second ten months, and eleven months in the third situation. Thus, an average which defined that between nine and ten months is the ideal time to clean the GO´s photovoltaic panel has been defined.

If it is considered that if you want a performance ratio of at least 72%, the overall average of all the functioning of the system would go to 73.45%. Similarly, it follows the same pattern held in the previous scheme. Thus, the average number of months for which the cleaning be done should be five to six months, in order to achieve a rate of minimum 72% performance throughout the year.

Values slightly higher than 72% are impracticable, since it presents a month-to-month variation and thus, not necessarily, the reduction of the merit indexes could be a consequence of dirt, that is, the cleaning will not affect effectively the system's performance.

When comparing the data from the Neoville's merit indexes, the cleaning performed did not show significant improvements to the system, therefore it was not possible to carry out a methodology to discover the optimal time for the cleaning of this system.
However, some aspects can be highlighted, as the Neoville's photovoltaic panel is inclined equally to its latitude, ideal slope for power generation, compared to the GO system, which has a lower slope than the latitude, the times when the system has better generation are in autumn and spring, but in the summer season, the system with a lesser slope than latitude, as in the case of the GO, presents the highest merit indexes, since the system receives more irradiation at this time of the year.

CONCLUSIONS

The electric energy is generated by several strands, one of them is photovoltaic solar energy, which has been growing considerably over time. This method of generating electric energy comes from the photovoltaic cells, which constitute a photovoltaic module. Several factors imply in the functioning of these modules, such as dirtiness.
Dirt on the surfaces of photovoltaic modules is directly related to the decrease in the efficiency of photovoltaic cells, which can be quite significant. The power output provided from a photovoltaic module depends heavily on the amount of irradiation reaching the panels. The dirtiness decreases the transmittance of the modules due to the scattering of the incident radiation, reducing the intensity that reaches the cell. So dirt limits the generation of electrical energy and consequently the productivity of the system.
Through the cleanings carried out, it was possible to observe the losses coming from the dirt. Some data of the productivity indexes of the studied panels were collected monthly, along with the performance ratio and the capacity factor. Through these data, it can be confirmed the decrease in the productivity and performance of the photovoltaic panels studied due the dirtiness.
The methods for the performance of this study started by the data collection of the constructive and electrical characteristics of the GCPVS, the solar radiation data in the horizontal level, the adaptation of the radiation values in RADIASOL and the calculations of the merit indexes for each system.
It was possible to monitor, study and develop satisfactorily the ideal time for cleaning the photovoltaic modules studied in the GO, but it was not possible to determine the ideal time for cleaning the panel located in the Neoville headquarters.
At the GO, it was stipulated two minimum performance ratios to act throughout the system operation. One of them was using a rate of at least 70%, which can determine that the ideal time for cleaning the panel was between 9 to 10 months. The other, with the value of the performance ratio changed to 72%, it was possible to verify that the ideal time changed for 5 to 6 months.
It could be noticed that values above those stipulated are impracticable for the determination of the optimum time, due to the climatic consequences that can change the levels of dirtiness, consequently causing excessive variation of the merit indexes and so implying in the need of more frequent maintenance, raising the costs with cleaning unnecessarily.
At the Neoville headquarters, all the data obtained from the merit indexes since its recent operation, have been analyzed. When analyzing the data, it was found that, in August 2016, even the GO having a lower radiation than Neoville, it still had higher productivity than the Neoville itself. With this, the energy that could be generated by Neoville was lower, consequently it had a lower productivity, a lower capacity factor and a lower performance ratio than it should have had. Although it cannot be stated, it probably is that this decrease in the merit indexes is due to the disconnection of the

inverter, which must be occurring over the months, especially in August 2016, which fell from 84.75% to 60, 23%. One of the reasons for this drop may be due to some error in the parameterization of the inverter or the excessive disconnections that occurred during the month. This excess of shutdowns means that it does not provide all the energy that the photovoltaic system could actually generate. Given these factors, it was not possible to determine the ideal time for cleaning the Neoville headquarters' photovoltaic panel, requiring more information to set the best time for that.

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