PID Analysis

MEUBELEN VERHAEGEN – BETEKOM, BELGIUM

3 December 2015

Reference:	RE-2015-00067
Client:	Edison Energy Davy Verheyden Grote Baan 115 3130 Betekom, Belgium
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General project information

Subject of this Study:	PID Analysis
Goal of this Study:	The goal of the PID analysis is to check if the respective PV system could be subject to Potential Induced Degradation. If this is the case, an estimation will be made of the increase in Performance Ratio when PID is resolved.
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Table 1: General Project Information

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1. INTRODUCTION

The aim of the PID analysis is to check if the respective PV system could be subject to Potential Induced Degradation. Based on a number of parameters, such as the Performance Ratio and the spread of the relative yield of the inverters, the presence of PID can be concluded. When there is any suspicion that PID is present, a test will be set up at the site. In this test, a number of inverters will be equipped with anti PID devices. The results of the test set-up will be used to estimate both the potential improvement of the Performance Ratio and the corresponding financial profits.

Currently, there are several anti PID devices on the market. These devices can regenerate the panels during the night. The panels can then generate their normal capacity during the daytime. Any judgement about any specific device is beyond the scope of this report.

The investigated site, Meubelen Verhaegen, is situated in Grote Baan 115, 3130 Betekom, Belgium. The site was installed in 2011 and includes a rooftop installation with a total installed capacity of 688 kWp.

Figure 1 : site Meubelen Verhaegen

2. Potential Induced Degradation

2.1. What is PID?

PID stands for Potential Induced Degradation. PID is a process that reduces the performance of photovoltaic cells. In normal circumstances the sunlight releases electrons which then flow to an inverter. PID prevents this process.

PID can occur because of negative voltages in the solar cells in relation to earthing. This is highly dependent on the type of inverter. The larger the negative voltages to which the panels are exposed, the stronger the PID effect can be. In the figure below, the PID effect will mostly be boosted by inverter 2. Inverter 4 on the other hand, has only positive voltages in relation to earthing. The PID effect cannot occur here.

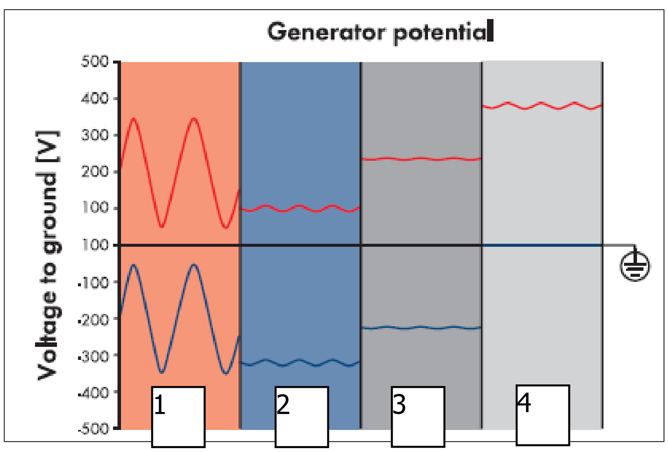

Figure 2 : String tensions in different types of inverters (source SMA)

PID is the result of the migration of positively charged particles, for example sodium ions, in the glass, towards the solar cells. As a result of large negative voltages, these ions are attracted to the cells and will be transmitted through the EVA film (Encapsulating material on figure 3) to the cells. This causes a short circuit in the cell, resulting in the gradual decline of the performance of the solar cells.

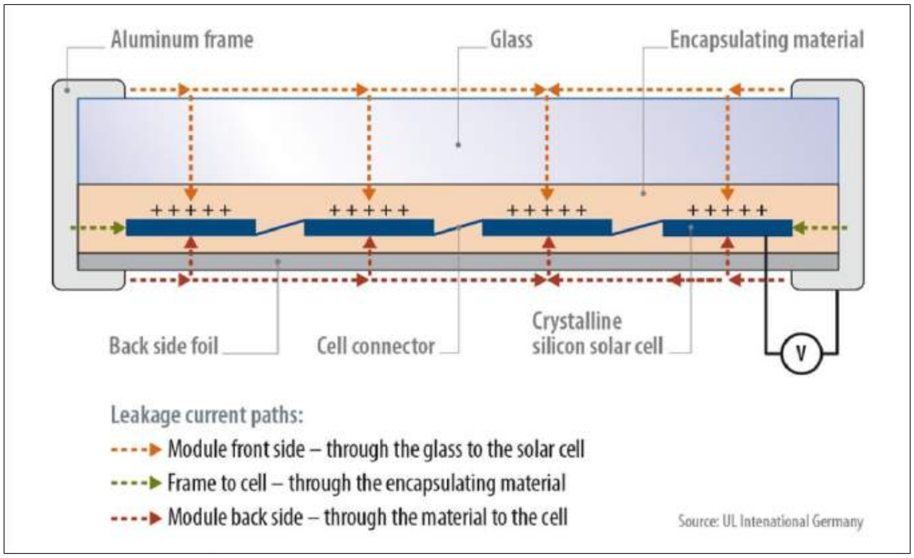

Figure 3 : Migration of ions (source: UL International Germany)

The following I-V curve illustrates the effect of PID on the performance of a solar cell. Under normal operating conditions, the solar cell has state 1 of the figure below. The surface area of the red rectangle represents the maximum capacity of the cell (the capacity is namely the product of voltage and current). When exposed to PID for a long period, the I-V curve collapses (state 2). It is clearly visible that the black rectangle (and the capacity of the cell) has become smaller. In certain cases, the module capacity can be reduced by more than 30%.

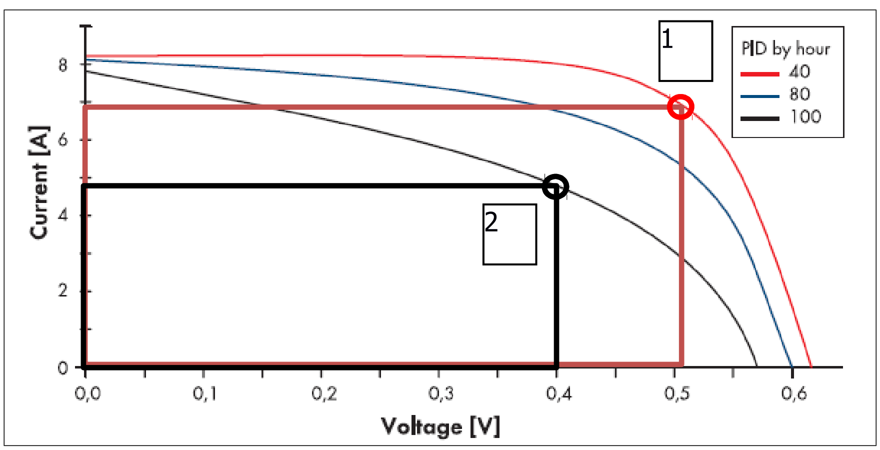

Figure 4 : Decline of the I-V curve (source SMA)

The PID effect can be made visible by means of an EL (electroluminescence) test, during which a current is sent through the panel and the emitted (infra-red) light is being observed. The images below illustrate the situation before and after the PID effect has taken place. One can see that modules affected by PID contain several cells that no longer work (properly).

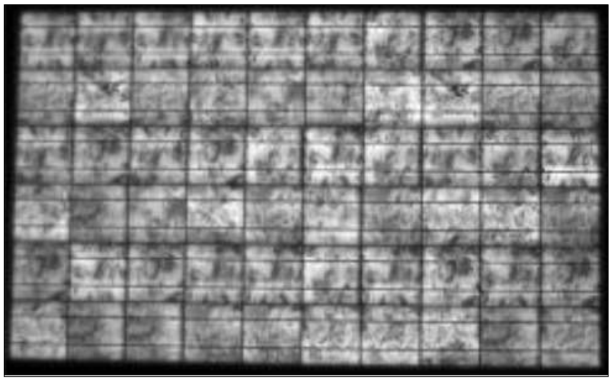

Figure 5 : EL test normal module

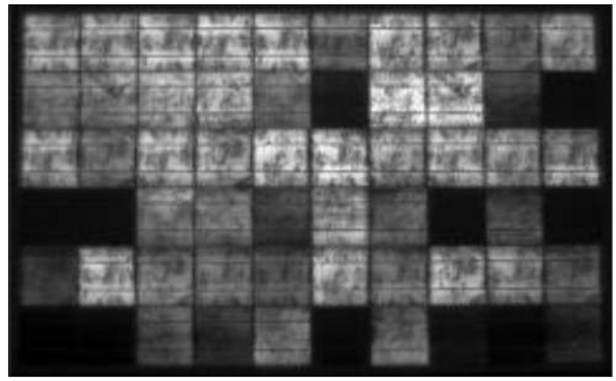

Figure 6 : EL test PID module

The extent to which the PID effect occurs, depends on several factors. Some type of solar panels can be more sensitive to PID because of a lower resistance towards the glass. As a result, ion migrations can occur faster and be larger.

Finally, environmental factors also play an important role. High temperatures and high humidity namely boost the PID effect.

1.1. CAN THE PID EFFECT BE RESOLVED?

The PID effect is reversible. Currently, there are several anti PID devices on the market. These devices can regenerate the panels during the night. The panels can then generate their normal capacity during the day.

This is made possible by providing the modules with positive voltages during the night. Hereby, the migrated ions will flow back to their original locations in the glass. However, it will take several days before the effect becomes noticeable. There are several devices on the market that can repeat this process on a daily basis. On average, the normal performance capacity of the cells is reached 1 month after the installation of these anti PID devices. Even after the PID effect has been resolved, these devices remain necessary as they prevent the PID effect from recurring.

3. PRE-ANALYSIS

3.1. DESCRIPTION OF THE SITE

The following table contains an overview of the parameters of the PV installation of Meubelen Verhaegen:

General Parameters	
Total installed capacity [kWp]:	688,16
Total amount of panels:	2.992
Tilt angel [°]:	15
Orientation panel surface [°]:	-6
Panel Parameters	
Brand & type:	Scheuten P6-60
Technology:	Polycrystalline
Nominal capacity [Wp]:	230
Capacity tolerance [%]:	+/-3
Nominal module output [%]:	0
Inverter Parameters	
Type:	String Inverters
Brand:	Aurora Power One
Model:	PV-I 12.5 OUTD
Transformer:	None
Total amount of inverters:	21
Max. yield [%]:	97,7
Euro-ETA-yield [%]:	97,25
Monitoring Parameters	
Type of monitoring system:	Synaptiq
Brand & type irradiation sensor:	None

Table 2 : Overview site parameters

3.2. DETERMINATION OF PERFORMANCE RATIO

In order to gain insights on the overall performance of the PV system, it is not sufficient to merely take the output of the PV system into account. This yield namely depends on the solar irradiation. Therefore, a relative low yield on an annual basis does not necessarily mean that the system has performed less. For this reason, it is useful to calculate the Performance Ratio (PR). The PR also takes the solar radiation for the corresponding period into account. For the PV system of Meubelen Verhaegen, the PR was calculated for October 2011 - September 2015.

3.2.1. DETERMINATION OF IRRADIATION

3.2.1.1. HORIZONTAL IRRADIATION

The irradiation is the total energy irradiated per unit area during a certain period [kWh/m²]. The global irradiation is the irradiation of the entire light spectrum of the sun on earth and is the sum of the direct and diffuse radiation. The global solar radiation can be measured with a pyranometer.

The figure below shows the global irradiation for Belgium. On an annual basis, this is approximately 1,000 kWh/m². [1]

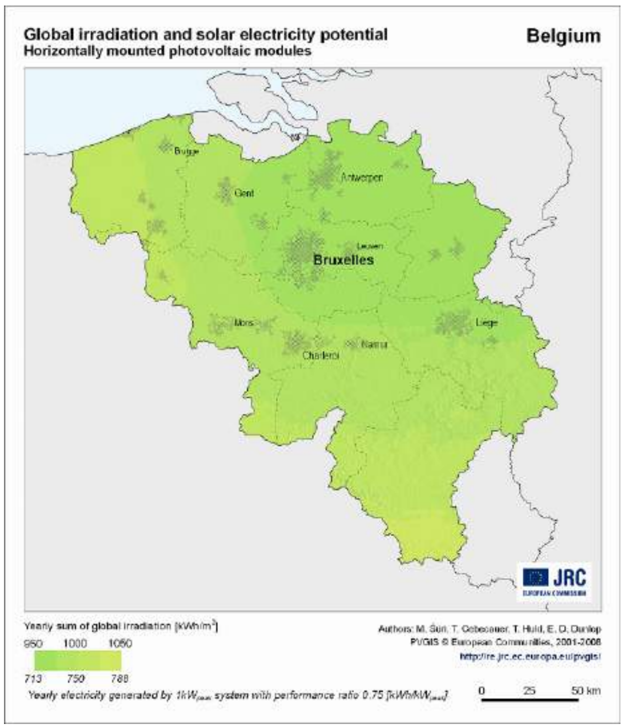

Figure 7: Global irradiation horizontally mounted PV modules in Belgium

3.2.1.2. IRRADIATION IN THE PANEL SURFACE

The irradiation in the panel surface depends on the tilt angle and orientation of the PV panel. The model of Hay was used for the transposition of the irradiation of the horizontal plane to the panel surface.

The following graph shows the orientation and tilt-dependent irradiation for the region of Betekom :

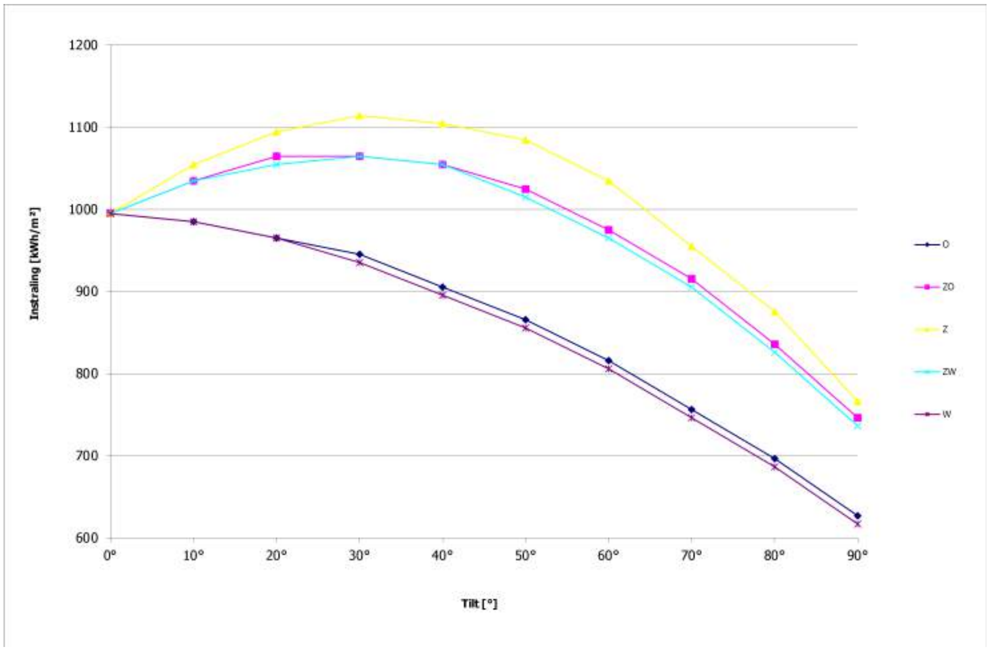

Figure 8 : Orientation and tilt-dependent irradiation region of Betekom

3.2.1.3. RADIATION ON THE SITE OF MEUBELEN VERHAEGEN

Since there is no reliable radiation sensor on the site, it was decided to use the radiation data from the nearest RMI (*Royal Meteorological Institute of Belgium*) station. For the region of Betekom, this is the RMI station of Sint-Katteliјne Waver. As these irradiation data are measured in the horizontal plane, the transposition model of Hay needs to be used to convert the data to the panel surface of the PV system of Meubelen Verhaegen. For the site of Meubelen Verhaegen, this was 108.1%.

3.2.2. DETERMINATION OF YIELDS

The revenue, expressed in kWh, for the corresponding period can be determined in two different ways. This can be either through the display of the inverters, or through the counter of the green power meter.

The yield for a certain period of time can be determined through the monitoring system, on the basis of the read-out of the individual yields of the inverters. This has the disadvantage of bigger inaccuracies of measurements.

The green power meter is the most accurate way to determine the yield because it registers the net energy produced for which green certificates are obtained. The green power meter may also be equipped with pulse contacts that allow to generate quarter values of the net energy production so this can be monitored via the monitoring system.

For the Meubelen Verhaegen project, the yield was determined based on the readings of the green power meter.

3.2.3. CALCULATING THE PERFORMANCE RATIO

The performance ratio (PR) is the quotient of the system output and the output of the modules at STC (Standard Test Conditions: 1000 W / m², 25 ° C, AM 1.5). The performance ratio is calculated as follows:

$$PR = \eta_{sys} / \eta_{STC}$$

(1 - PR) is a unit of the losses of the system and includes amongst others loss factors such as irradiation losses, inverter losses and cable losses

3.2.3.1. LOSSES

The losses of a PV system can be divided into different categories. In the calculation of the performance ratio, following losses are taken into account:

- Irradiation losses: losses from shading, reflection losses and low irradiation losses;
- Inverter losses: output losses, sizing losses;
- Ohmic losses: cable losses;
- Other.

3.2.3.2. DETERMINATION PERFORMANCE RATIO

For this report, the performance ratio was calculated on the basis of the information available, as listed in this document. The following table contains an overview of the annual PR for the Meubelen Verhaegen site for the period October 2011 - September 2015.

Period	Absolute Output [kWh]	Relative Output [kWh/kWp]	Irradiation [kWh/m²]	PR [%]
Oct 2011 – Sept 2012	678.526	986	1.134	86,9%
Oct 2012 – Sept 2013	623.473	906	1.109	81,7%
Oct 2013 – Sept 2014	635.860	924	1.149	80,4%
Oct 2014 – Sept 2015	649.073	943	1.194	79,0%

Table 3 : Overview performance ratio

A normally functioning system should have a Performance Ratio of at least 80%. With a Performance Ratio of **79.0%** for the period October 2014 - September 2015, the PV system at Meubelen Verhaegen underperformed. The table above clearly shows that the PR is decreasing.

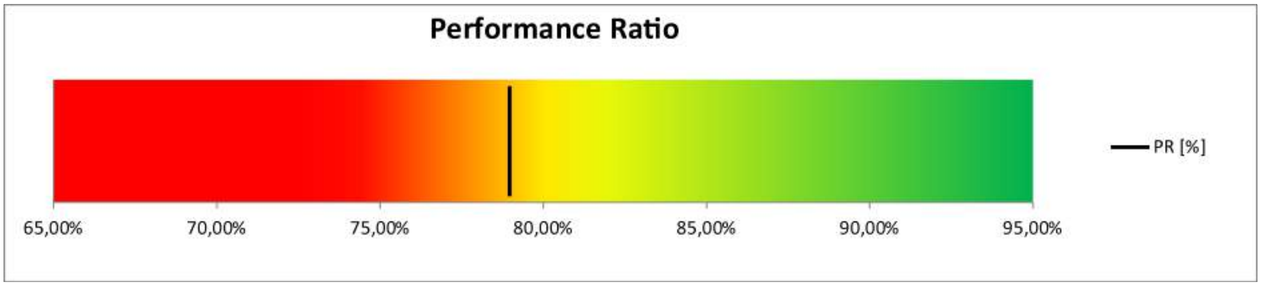

Figure 9 : Situating Performance Ratio October 2014 – September 2015

3.3. INVERTER SPREAD

If PID is present in a PV system, it is not evenly distributed across the panels and inverters. By comparing the performance of the inverters an additional indication of PID is revealed. This can best be visualised by comparing the string voltages to the inverters (when the solar panels are operating) with each other. These voltages are namely less dependent on inclination and orientation of the solar panels. This data is however often not available. In that case, it is possible to analyse the individual yields of the inverters.

The data for this analysis is obtained from the monitoring system and is based on the reading of the inverters. So, the absolute yield can hereby differ from the one of the green power meters. Since these data are only used to compare the inverters to each other, this is however irrelevant. The inverters were compared for the period October 2014 - September 2015. All inverters have panels with a similar orientation and inclination. The chart below displays the relative yield expressed in kWh/kWp for the corresponding period:

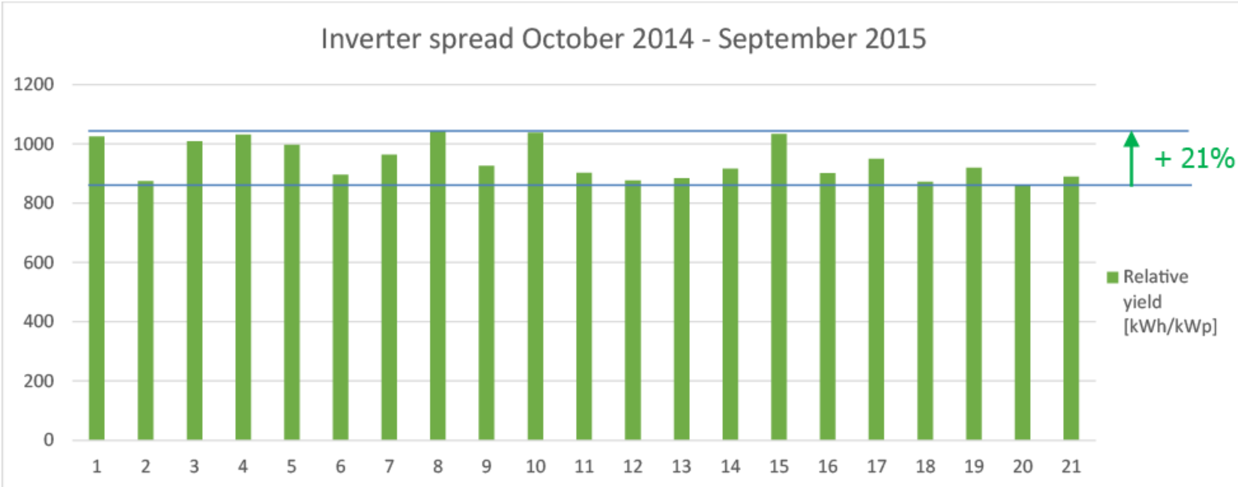

Figure 10 : Distribution relative yield

If we don't take the abnormal values into consideration, we have a ratio of 121% between the largest and the smallest value. A normal operating system with the same orientation and tilt angle of solar panels, should have a spread less than 110%.

3.4. Conclusion pre-analysis

A low Performance Ratio, as calculated in paragraph 3.2.3.1, can be caused by different types of losses. If the low PR cannot be attributed to certain losses, chances are that PID is present. This is the case for the PV system of Meubelen Verhaegen. The PR is below average and there are no visible factors that could explain the substandard performance. Furthermore, it is clear that the PR has inclined to a great extent (from 86.9% in year 1 to 79% in year 4), which is an indication of the presence of PID.

The spread of the relative yield of the inverters is huge. A spread of 121% is a further indication of the presence of PID. It is therefore recommended to set up more tests.

Experience has shown that the combination of Scheuten solar panels and Aurora Power One inverters is sensitive to PID.

4. Test set-up

4.1. Selection of the inverters

From paragraph 3.3 it is clear that several inverters are performing significantly less in comparison to the other inverters. Therefore, the inverters were divided into three groups, namely: best performing, mediocre performing and least performing inverters. For this test set-up two inverters were selected for each group. For the test at Meubelen Verhaegen, these are the following inverters:

- Inverters 3 and 4: two best performing inverters;
- Inverter 14 and 16: two mediocre performing inverters;
- Inverters 12 and 13: two least performing inverters.

The figure below shows the relative yield per inverter for the period October 2014 - September 2015. The relative yield is the quotient of the amount of generated kWh and the amount of kWp solar panels connected to the inverter.

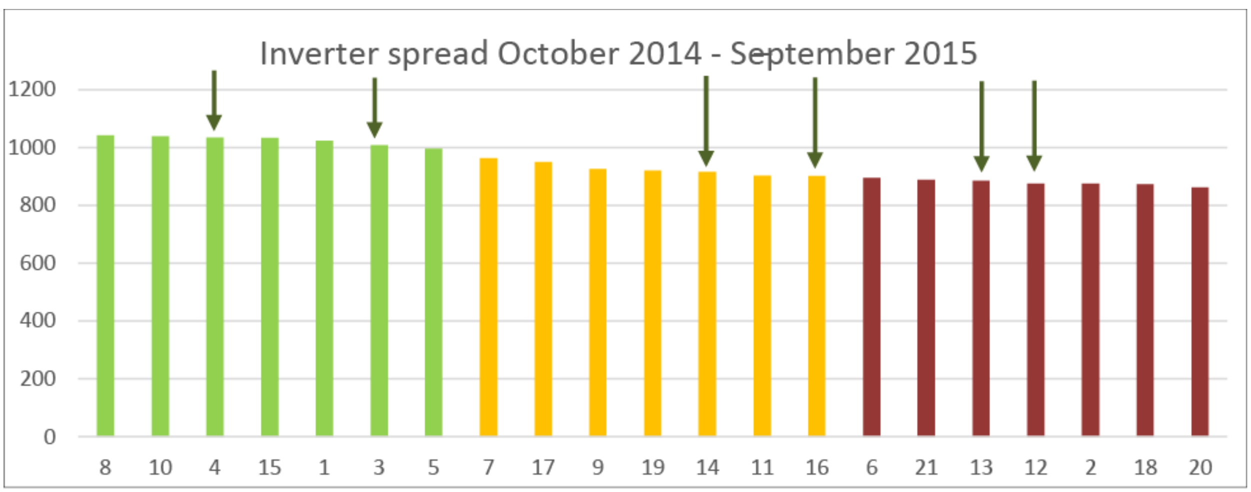

Figure 11 : Selection of the test inverters

4.2. Test description

For this test, the Pidbull technology of Edison Energy was used. In this application, the + and - ends of all the corresponding strings are required in order to be able to regenerate the solar cells. Since the strings are connected in parallel on every MPP tracker (Maximum Power Point), it is sufficient to connect the units to 1 string per MPP tracer. This can be done by using an available output of the MPP-tracker, or by using a T-piece.

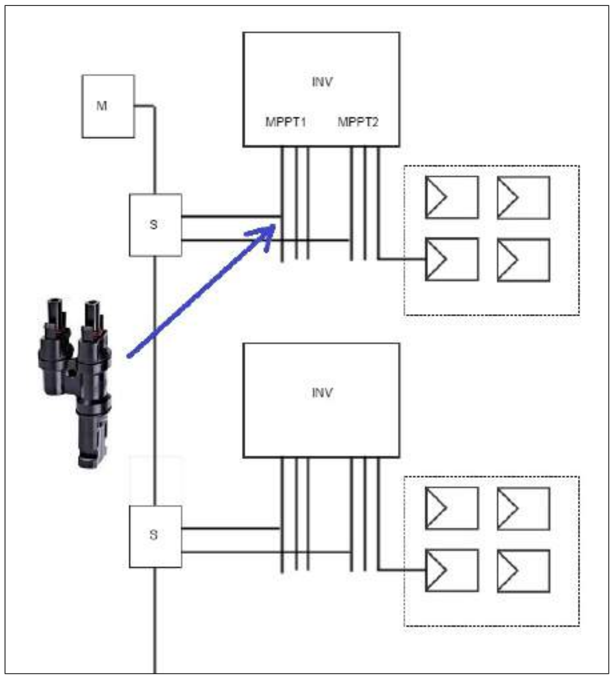

Figure 12 : Schematic presentation of the connection of PID boxes

The pictures below show an overview of the test set-up.

Figure 13 : Overview test set-up

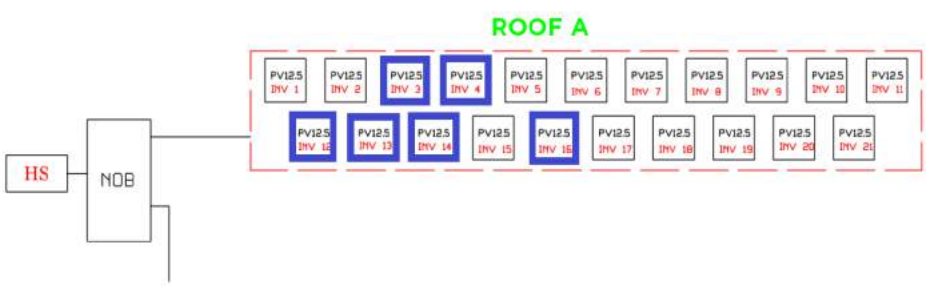

Figure 14 : Overview selected inverters

In this test, the PID box of Edison Energy is connected to the free DC inputs of the inverter.

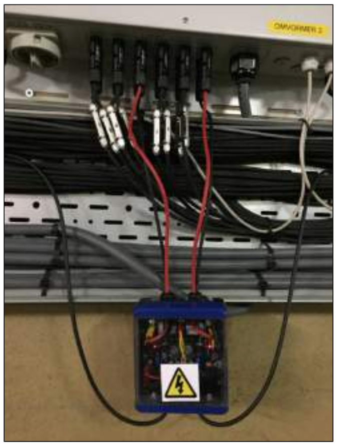

Figure 15 : Slave box to inverter

Figure 16 : Connection to available inputs

4.3. Test results

4.3.1. Comparison towards the average

Based on the monitoring system, the relative yields of the inverters in kWh / kWp were analysed in the period before and after the installation of the PID boxes (± 20 days before and after). The commissioning of the PID box started on 20/09/2015. The table below shows the relative yield of the respective inverters compared to the average of the inverters which have not been tested. This way, the tested inverters have no impact on the average and the performance with respect to the same reference can be compared.

	Best		Mediocre		Least	
Date	Inv. 3	Inv. 4	Inv. 14	Inv. 16	Inv. 12	Inv. 13
2015/08/31	106%	108%	99%	98%	94%	95%
2015/09/01	107%	111%	99%	96%	93%	94%
2015/09/02	107%	109%	100%	98%	94%	96%
2015/09/03	107%	110%	100%	99%	94%	96%
2015/09/04	107%	111%	98%	96%	94%	94%
2015/09/05	106%	111%	99%	97%	94%	95%
2015/09/06	107%	111%	99%	98%	94%	95%
2015/09/07	107%	112%	99%	96%	94%	95%
2015/09/08	106%	112%	98%	95%	94%	94%
2015/09/09	107%	110%	99%	98%	95%	95%
2015/09/10	107%	109%	99%	98%	95%	96%

	Best		Mediocre		Least	
Date	Inv. 3	Inv. 4	Inv. 14	Inv. 16	Inv. 12	Inv. 13
2015/09/11	107%	109%	99%	98%	94%	96%
2015/09/12	106%	112%	98%	96%	94%	95%
2015/09/13	107%	112%	99%	96%	95%	95%
2015/09/14	107%	112%	99%	97%	95%	96%
2015/09/15	107%	111%	100%	98%	95%	97%
2015/09/16	106%	114%	98%	95%	94%	95%
2015/09/17	107%	115%	98%	95%	95%	95%
2015/09/18	107%	111%	99%	98%	95%	97%
2015/09/19	107%	113%	98%	96%	95%	95%
2015/09/20	108%	112%	99%	99%	95%	96%
2015/09/21	107%	112%	100%	98%	96%	97%
2015/09/22	110%	114%	104%	102%	100%	102%
2015/09/23	114%	118%	107%	103%	103%	105%
2015/09/24	113%	116%	107%	105%	103%	105%
2015/09/25	113%	114%	108%	108%	103%	105%
2015/09/26	112%	114%	107%	107%	104%	105%
2015/09/27	113%	114%	107%	107%	104%	106%
2015/09/28	113%	115%	109%	108%	105%	107%
2015/09/29	113%	114%	108%	108%	104%	106%
2015/09/30	113%	114%	109%	108%	105%	107%
2015/10/01	113%	114%	108%	108%	105%	106%
2015/10/02	113%	114%	108%	108%	105%	106%
2015/10/03	114%	114%	109%	109%	105%	107%
2015/10/04	114%	115%	109%	109%	105%	107%
2015/10/05	117%	119%	111%	110%	107%	109%
2015/10/06	119%	120%	113%	112%	110%	111%
2015/10/07	121%	123%	115%	114%	112%	113%
2015/10/08	121%	122%	115%	114%	112%	113%
2015/10/09	116%	117%	113%	114%	110%	112%
2015/10/10	123%	125%	116%	115%	114%	115%
2015/10/11	117%	117%	112%	113%	111%	111%
2015/10/12	118%	118%	114%	114%	111%	112%
2015/10/13	123%	124%	115%	115%	113%	114%
2015/10/14	125%	127%	117%	116%	114%	116%

Table 4 : Performance of inverters compared to the overall average

The above table shows that inverters 3 and 4 perform above the average, inverters 12 and 13 produce below the average, and inverters 14 and 16 produce on average before the installation of the PID boxes. After the installation of the PID boxes, the least performing inverters quickly start showing an increase.

The evolution of the relative yields of the inverters are shown in the following figures. A reference inverter was picked for each group of inverters. The figure below shows the evolution of the best performing inverters.

Figure 17 : Evolution best performing inverters

The figure below shows the evolution of the mediocre performing inverters.

Figure 18 : Evolution mediocre performing inverters

The figure below shows the evolution of the least performing inverters.

Figure 19 : Evolution least performing inverters

4.3.2 INDIVIDUAL IMPROVEMENT OF THE INVERTERS

In order to determine the individual improvement of the inverters, the output of the respective inverter will be compared to the average before and after the tests. Since the performances vary slightly on day basis (see values Table 3) an average was taken of the values of Table 3 for the period of 1 week. This results in the following table:

	Good		Mediocre		Bad	
Period	**Inv. 3**	**Inv. 4**	**Inv. 14**	**Inv. 16**	**Inv. 12**	**Inv. 13**
2015/09/13 - 2015/09/19	107%	112%	99%	96%	95%	96%
2015/10/08 - 2015/10/14	120%	121%	115%	114%	112%	114%
Increase	**113%**	**108%**	**116%**	**119%**	**118%**	**119%**

Table 5 : Performance of inverters compared to the overall average

From the above table, it is clear that the generation of the tested inverters has increased with more than 10%. The increase is the biggest for the poor and mediocre performing inverters (± 16% increase) but also in the high-performance inverters there is a big increase of ± 10%.

5. Final conclusion

Based on a number of parameters, such as the Performance Ratio and the spread of the relative yield of the inverters, there was an indication for the presence of PID. Therefore, a test was set up at the site in which a number of inverters were equipped with anti PID devices. Based on the results of this test set-up, an estimation will be made of the potential improvement of the Performance Ratio and the corresponding financial profits.

This analysis shows that all tested inverters have an increased output. The increase is the most distinct in the worst performing inverters (± 16% increase) but also in the high-performance inverters there is a strong increase of ± 10%. Since the data were examined up to 25 days after the PID boxes had been commissioned, it is possible that the increase will partly continue.

The tests were conducted in the period September - October. This result can however not be extended for a full year. But an overall increase in yield of 5% to 10% is therefore not unrealistic. This corresponds to an increase of 32,454 kWh to 64,907 kWh for the period October 2014 - September 2015. If we consider an injection rate of € 0.035 / kWh (100% injection) and a minimum support of € 0.33 / kWh, a potential profit of € 11,846 to € 23,691 can be obtained for the corresponding period.

Figure 20 : View site Meubelen Verhaegen

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Do you only need advice or a design? That is possible because Encon always provides solutions tailored to your business. Whether you are an SME or a large enterprise, we think along with you throughout the project. We develop cost effective solutions as if they were our own investments. This way we aim to create a clear added value for your business. Because your success is our starting point.

FROM STUDY TO SUBSIDY

Encon retains the control over and responsibility for the entire project. The separate stages are perfectly aligned. This leads to a result in which a financial return plays a central role. Besides, as an engineering agency, Encon can rely on years of practical experience and a passionate team of energy experts. They not only develop solutions, but also investigate funding opportunities. Premium applications themselves are also handled by Encon. In short: a total solution in the broadest sense of the word.