

Degradation Measurements Of Aged PV Modules

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ABSTRACT: Degradation measurements of aged PV modules with an operation time of about 8 to 12 years have been carried out. Only crystalline modules have been investigated. It will be distinguished between two groups. The first group of modules is coming from the photovoltaic promotion program “Sun at School” and from two larger PV plants in southern Germany. All they went in operation between the years of 1994 and 1997. No reference is available for this group. The second group of modules is coming from the 1 MW_p PV system Munich Trade Fair Centre, they were installed in 1997. For them a reference – non illuminated modules – is available. Within the first group, some faulty modules have been detected. It can be stated, that after 8 to 12 years of operation no module reaches its nominal power. This effect can come from degradation, but can also come from the fact, that the original nominal power was considerably smaller than the value on the label. After nearly 8 resp. 9 years of operation, the modules of the 1 MW_p PV system on the Munich Trade Fair Centre show degradation values of 2.4 up to 4.0 %. The measured output power of the “dark” modules at STC is nearly the nominal power, thus these modules serve as a reference.

Keywords: Degradation, PV Module, Crystalline

1. GENERAL

1.1 Degradation

The item “Degradation” is often applied. Practically, this is the decrease of output power within the lifetime of a module. Degradation may depend on many parameters, some of them can be:

- Pollution of the module’s surface
- Haze of the laminate and delamination
- Aggravation of the contacts, i.e. by mechanical stress and dampness
- Light-induced degradation and thus a decrease of solar cell efficiency under illumination may occur. The reason is a formation of a defect which is correlated to the simultaneous presence of boron and oxygen in the material [1].

The purpose of this work is to report about the degradation measurements of aged PV modules with an operation time of about 8 to 12 years.

1.2 Modules investigated

Only crystalline modules have been investigated. In this paper it will be distinguished between two groups. The first group of modules is coming from the photovoltaic promotion program “Sun at School” which is operating PV systems of 1 kW_p in over 900 schools nearly almost in the whole of Germany. Additionally to this group contains modules of two larger PV plants in southern Germany. They all went in operation between the years of 1994 and 1997. No reference is available for this group.

The second group of modules is coming from the 1 MW_p PV system Munich Trade Fair Centre, they were installed in 1997. For them a reference – non illuminated modules – is available.

The main criteria for the module selection was the easy accessibility to the PV generator, not the yield.

Within the investigation the output power at STC has been evaluated.

Figure 1 illustrates three example locations of the modules. After long years of operation they are in a good condition.



Figure 1: 1 kW_p school PV system installed in 1995 (above), 50 kW_p system (1994 - middle), 1 MW_p PV system Munich Trade Fair centre (1997- below)

1.3 Organisation

The measurements have been carried out by two independent laboratories. They will be called Lab A – with a measurement uncertainty for power values of $\pm 5.0\%$ - and Lab B with $\pm 3.5\%$. Three measurement series have been carried out; they will be described and analyzed in following:

1. First investigations have been carried out in the year 2005, only using the services of Lab A.
2. The next ones took place about a year later in 2006, when modules were sent to Lab A again.
3. In 2006 additional measurement were done by Lab B.

Not all modules took part on all measurements. However degradation measurements have been carried out three times for some modules. **Table 1** indicates that the number of modules is sufficient to make qualified statements.

Table 1: Module measurements in two laboratories

	Sun at School	Munich Trade Fair Centre
2005 Lab A	30	12
2006 Lab A	17	6
2006 Lab B	11	6

2. RESULTS

2.1 Sun at School

2.1.1 Measurements in 2005

In January 2005 in total 30 modules from two manufacturers and of six types have been analyzed by Lab A. 12 of the modules had nominal powers between 50 and 55 W_p , the rest showed values between 100 and 120 W_p . They have been manufactured in the years 1993 to 1998.

All the modules showed little haze; only a rough cleaning was carried out before the measurements. They were undamaged with two exceptions. One Module had a burn hole on the backside, two others showed delamination. The glass surface did not show any haze.

Figure 2 illustrates the results for all 30 modules which were investigated.

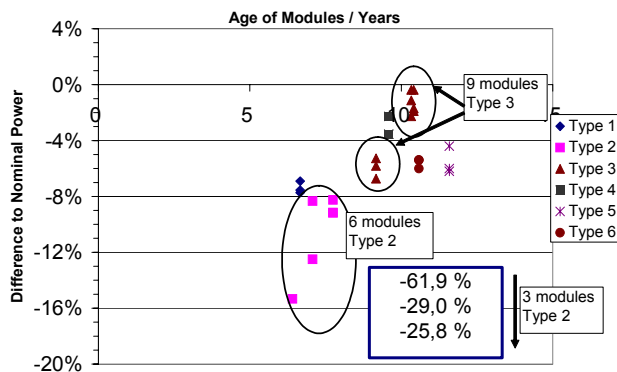


Figure 2: Degradation of 30 modules, measured in January 2005 in Lab A

As no measurements exist for the modules when they were installed, nominal power has to serve as reference. Thus the values on the y-axis indicate the appropriate difference.

Referring to Figure 2, the various modules are indicated as Type 1 to Type 6. The degradation results for one type always lie together. However the values spread over a wide range, from nearly 0% to more than -60%. The modules with more than -25% have been replaced in the meantime; they were out of faulty production.

What can be seen, if the faulty modules are excluded? It can be stated, that after 8 to 12 years of operation no module reaches its nominal power. On this base the next step has been done.

2.1.2 Measurements in 2006

A second round of measurements has been carried out from May to July 2006. 17 modules in total were sent to Lab A, they had already been measured in Lab A in the year 2005, and the appropriate measurements were repeated in 2006. Eleven modules were measured as well by Lab A and Lab B. Naturally the faulty modules – with the high degradation values 2005, see Figure 2, had been eliminated.

Figure 3 indicates the measurements carried out only in Lab A in 2005 and 2006. The results obtained in 2005 have been confirmed. All differences of the measured power to the nominal power – for the appropriate types - in the two years lie close together, the trends are equivalent.

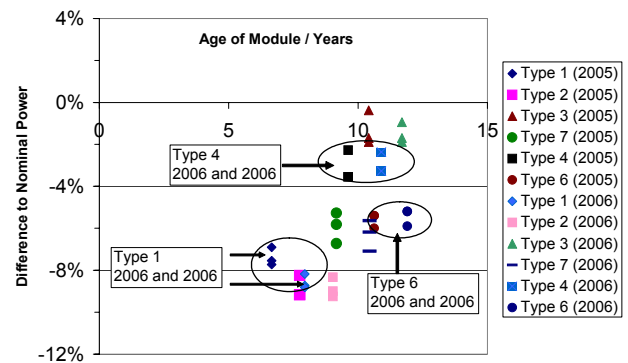


Figure 3: Degradation of 35 (18 in 2005 and 17 in 2006) modules measured in January 2005 and in May 2006, both in Lab A

It can be stated again, that after long years of operation no module reaches its nominal power.

This effect can come from degradation. It can also come from the fact, that the original output power (STC) at the time the module was installed - was considerably smaller than the value of the nominal power on the label. In this context [2] refers to measurements of more than 100 types of modules, which have been carried out in the years 2000 – 2004. Only a very small number showed a power (STC) greater than the nominal power. For most of the modules a considerable difference to the nominal power has been detected. 40% of the modules had power values far below the permitted range of tolerance.

2.2 Munich Trade Fair Centre

2.2.1 Measurements in 2005 and 2006

Twelve modules from this 1 MW_p PV system were sent to Lab A in May 2005. Six of the modules had been in operation since 1997, six were spare modules which had been in a dark store since the beginning of the operation. All the modules came from one manufacturer and were of the same type.

Some more measurements were carried out one year later in May 2006. The output power at STC of three modules in operation since 1997 and three „dark“ modules has been precisely determined.

One of the most important results is that the „dark“, non illuminated modules, directly coming from the store, showed nearly the nominal power. The exact mean value of all measurements carried out in 2005 and 2006 is 129,7 W for a 130 W_p module. Thus the nominal power may serve as reference.

The results of all measurements in both years can be seen in **Figure 4**.

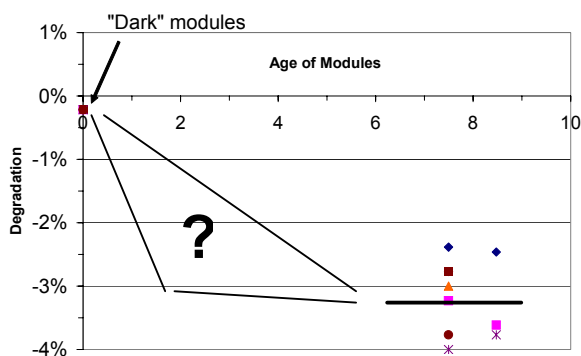


Figure 4: Measuring (Lab A) of six „dark“ and six illuminated modules in 2005 and three „dark“ and three illuminated modules in 2006

After nearly 8 resp. 9 years of operation degradation values of 2.4 up to 4.0 % have been measured. As the „dark“ modules proof, nominal power is valid as a reference. It can be seen, that certain degradation exists. However, no statement can be made about the development of the curve, the number of sampling points is too small, i.e. degradation values at ages 1, 2, 4 and 6 years would be necessary.

2.3 Comparing measurement results of Lab A and Lab B

2.3.1 Sun at School

Most of the measurement had been carried out in Lab A. All the statements made are on the base of the results of Lab A, measurement uncertainty for power values of $\pm 5.0\%$.

Eleven modules out of the group „Sun at School“ (Nine of them with nominal powers of 55 W_p, two with 100 W_p) have also been measured in Lab B with measurement uncertainty $\pm 3.5\%$ for power. **Figure 5** compares the results. It can be seen that the results of both labs follow the same trend. However the results of Lab B are systematically below those of Lab A. Normally the differences are smaller than 1 %, in one case 2 % - a 100 W_p module - are obtained.

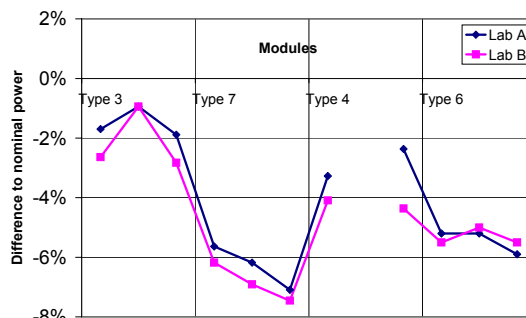


Figure 5: Degradation measurement – modules from Sun at School - of Lab A compared to Lab B

2.3.2 Munich Trade Fair Centre

Six modules of the same type have been measured in Lab A and Lab B. **Figure 6** shows the values obtained. The results of Lab B are again systematically below those of Lab A, but the trends are the same. For illuminated modules, the difference is nearly 2 %, for the „dark“ modules about 1 %.

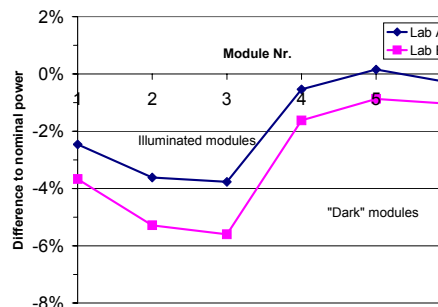


Figure 6: Degradation measurement - Modules Munich Trade Fair Centre - of Lab A compared to Lab B

3. CONCLUSION

It can be stated, that after long years of operation no module - out of the group „Sun at School“ - reaches its nominal power. No reference is available, thus this effect can come from degradation, but as well from the fact, that the original output power (STC) at the time the module was installed - was considerably smaller than the value of the nominal power on the label.

For the modules of the Munich Trade Fair Centre a reference is available, non illuminated modules, which show nearly the value of the nominal power. After 8 resp. 9 years of operation the illuminated modules show degradation values of 2.4 up to 4.0 %.

Some modules have been measured in two labs. A comparison shows that the results of Lab B are about 1 - 2 % below those of Lab A, the trends are the same.

4. REFERENCES

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