OP-14. Development of Design of Solar PV Panels within Last 25 years – Possibilities for Renovation

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Encapsulation of solar cells is most important for PV panel durability and reliability. Because of extreme market competition both quality and "quantity" of components of new PV panels is reduced compared to older design. Results in reduced reliability/durability of new PV panels compared to old ones. For instance, Solarex and/or Kyocera were producing PV panels for more than 30 years and they provided workmanship warranty 5 years. Manufacturers of new PV panels last typically about 10 years but they offer workmanship warranties in the range 12-25 years. The PV panel with warranty 25 years is in production 1-2 years only. The article compares in detail technical parameters of encapsulation between older and new PV panels. New PV panel renovation method was developed and tested for more than 5 years in real field conditions.

Keywords: Photovoltaics, Reliability, Renovation

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Abstract. Encapsulation of solar cells is most important for PV panel durability and reliability. Because of extreme market competition both quality and "quantity" of components of new PV panels is reduced compared to older design. It results in reduced reliability/durability of new PV panels compared to old ones. For instance, Solarex and/or Kyocera were producing PV panels for more than 30 years and they provided workmanship warranty 5 years. Manufacturers of new PV panels last typically about 10 years but they offer workmanship warranties in the range 12-25 years. The PV panel with warranty 25 years is in production 1-2 years only. The article compares in detail technical parameters of encapsulation between older and new PV panels. New PV panel renovation method was developed and tested for more than 5 years in real field conditions.

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1 Introduction

The PV panel encapsulation is determining trouble free lifetime of the panel. Because of strong market competition both quantity and quality of encapsulating components was reduced within last 25 years. Namely in tropical climate the PV panels trouble free lifetime can be as short a 3-12 years [1] . New solar PV panel renovation technology was developed and tested in real field conditions for period of 5 years.

Within last 25 years parameters of the PV panel encapsulation has been changed as shown below.

2 PV panels parameters changing

2.1 Frames

Average PV panel frame height is about ~35mm for many years. But the usual PV panel area is 4 times larger now. The load carrying frame length is double now. The consequences for PV panel frame bending is as follows:

Max. frame bending depth is

$$V_{max} = 5\ ql^4/384\ EJ_z$$

Where q is load (wind or snow), l is length of the frame, E is Young modulus of elesticity and Jz is momentum of inertia.

Lets estimate the PV panel frame cross section and frame material is the same so 5 /384 EJ_z is constant k.

Then $V_{max} = 5/384\ EJ_z * ql^4 = k * ql^4$, where l is length of the frame and q is load (wind or snow). Recently length of PV panel frame is twice as long compared to 25 years old one so l=2. The PV panel wind or snow load per frame length is q=2. If q=2 and l=2 , than

$$\boldsymbol{V_{max} = k * 2 * 2^4 \text{ and } V_{max} = k * 32.}$$

So the idealized PV panel load carrying frame bending depth is increased 32 times. The approximate estimate indicate substantial reduction of the PV panel frame strength. Theoretically the PV panel frame could be supported in 3- 4 points but all recent manufacturers installation instructions describe frame support in 2 points.

Another fact is that originally the frames were always fixed to PV laminates by continuous all arround sealing/glueing. Recently the frames are often fixed to PV laminate by a few tiny points of glue. There are about four 0.5 cm glue spots within 170 cm of frame length. So the frame fixig force is reduced substantially. Even more important is that the PV laminate edges are not sealed enough. It results in fast edge delamination failure [2].

2.2 Back side polymer laminate

Concerning PV panel back polymer film laminate originally the best quality PVF (Tedlar) film was used. Recently much less durable films like PVDF, PET, PA, PP …etc. are usual. The polymer film thickness was reduced by about 100 microns. Additionally typical PV array system voltage increased from about 600 V DC to 1500 V DC. So quality of insulation/encapsulation materials should be increased rather than decreased

Finally many new PV plants were installed in tropical locations with demanding climate. The result is fast ground impedance (Risol) decrease in real field conditions, caused by degradation of PV panel back sheet (see Fig 1).

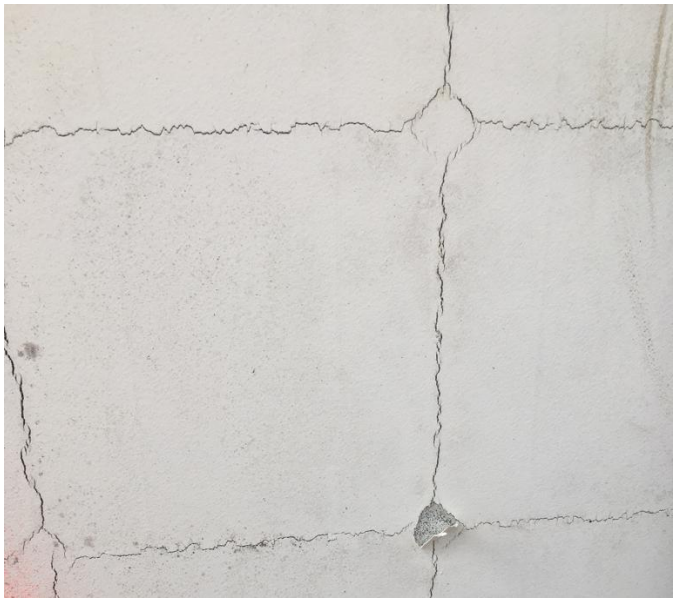

Fig. 1. PV panel back sheet degradation

2.3 Glass

PV panel front glass thickness was in the range 4.0-3.2 mm 25 years ago. Recently the front glass thickness range from 3.2 mm to 2.8 mm. But the usual PV panel glass area is 4 times larger now. The 2.8 mm thin front glass gives much lower hailstone protection compared the 4 mm thick glass [3].

At glass/glass PV panels the usual front glass thickness was 3.2 mm but it was decreased to 2.0 mm or even to 1.6 mm despite the PV panel area being four times larger.

The troubles with very thin 2.0-1.6 mm glass are as follows:

a) Limit glass thickness for standard temperature hardening is 3mm. Because of technological reasons the thin glass 2 mm or below is not hardened by standard way but a bit "improved" only. Cracks in these thin glasses are very frequent namely in large area PV panels.
b) The very thin glass offer low protection to brittle solar cell again hail stones [3] namely in large area PV panels.
c) The product of the PV panel encapsulating EVA polymer decomposition (acetic acid) can not escape out of the glass/glass PV panel. On the other hand the glass/polymer film PV panel design enables substantial escape of the corrosive acetic acid out of the panel trough the thin polymer back sheet.

2.4 PV panel real field lifetime

Recently there are reports that many IEC 61215 standard certified PV panels mainly in demanding/tropical climate last less than 12 years or even less than 4 years [1] with annual degradation rate above 2% (see Table 1) to reach total output power degradation

limit 80% although commercial leaflets declare PV panel lifetime 25-30 years to 80% degradation. Table 1 illustrates two degradation groups: the first group with a panel lifetime of up to 12 years and the second group with a lifetime of up to 4 years. There are numerous additional reports on degradation, but they often remain unpublished due to the confidential nature of the data following early failures in PV power plants. An example of such rapid degradation occurred in an 86 MWp PV power plant in South Africa, where substantial output power reduction was observed just 3.5 years after the plant's opening, caused by PV panel back sheet degradation. This example aligns with the second degradation group, although exact data remain confidential [4].

Table 1. Annual degradation of usual design glass/polymer film c-Si PV panels in demanding climate [1].

Location	Ghana	India	Algeria	Algeria	Morocco	India	Thailand	Senegal	S.Africa
Degradation (%)	3.19	2.5	3	2.6	2.6	20	2.7	2.96	5.5
Outdoor exposure (years)	12	10	11	11	3	2.5	3	4	3

Even in moderate climate of Europe [2,5] fast (7-12 years) PV panel degradation is many times related to back sheet degradation, resulting in reduction of ground impedance (Risol). Because of high degradation rates the damaged PV panel replacement expenses at PV power plants are strongly increased and some of them have to be dismantled after 3-12 years far before 25-30 years expected lifetime.

2.5 Workmanship warranty

Detailed survey of the workmanship warranty in 10s PV panel leflets from 1st tier companies arround the globe show results as follows:

Till the year ~ 2012 majority of manufacturers declared workmanship warranty 5 years. Later it was increased to 10 years and since the year ~2019 is was further increased to 12/15 years by majority of PV panel manufacturers. Since the year 2023 several manufacturers offer workmanship warranty 25-30 years. see Fig. 2.

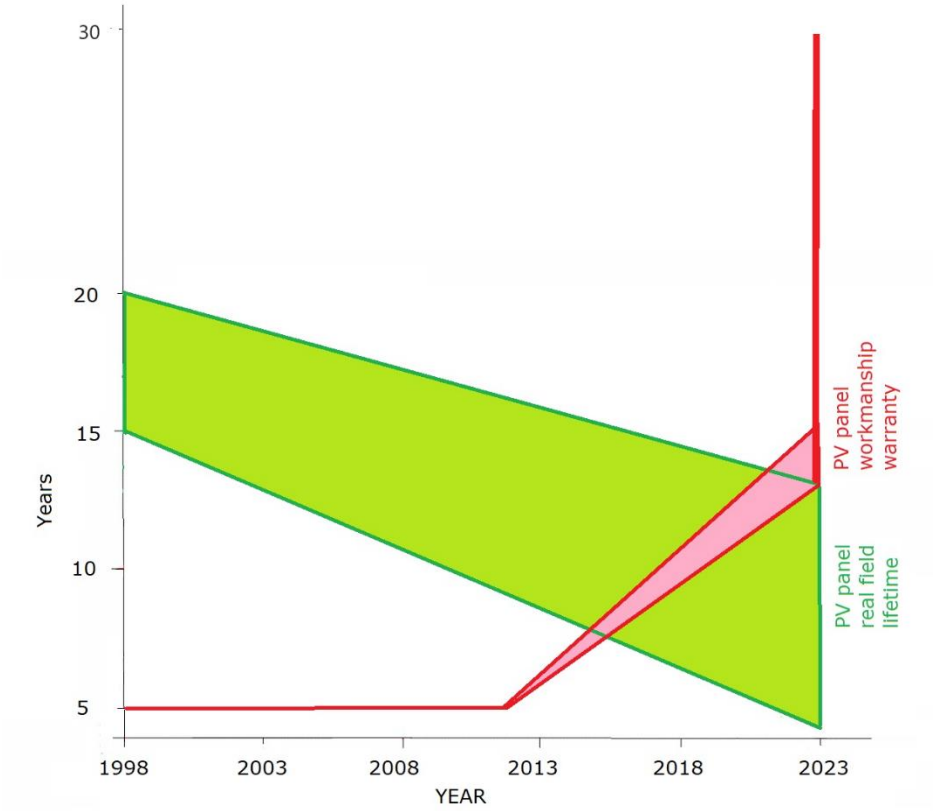

Fig. 2. Development of workmanship warranty period within last 25 years period compared to real field PV panel lifetime.

2.6 PV panel recycling

PV panel lifetime reduced to 3-12 years namely in demanding/tropical climate will influence PV panel recycling business substantially. The recycling companies expect surge of PV panels recycling demand within 15-20 years. But it could happen already within about ~5 years. It is question if the recycling companies are ready for such change? For instance in the Czech republic after PV power plant installation boom in the year 2008 large recycling companies expected recycling surge in the years 2033-2038 but there is high demand for recycling just now (2023). Some large recycling companies are in big financial troubles. At least one is bankrupt. PV panel renovation technology could help to solve the trouble. It could be possible to shift the recycling date by 5-10 years.

3 Results

3.1 PV panel renovation

The standard way is replacement of damaged PV panels by new ones. It is expensive and not effective from the carbon footprint point of view. Several technologies of on site PV panels renovation were tested [2, 4]. Some of them are using thin (about 0.1 mm) polysiloxane (PDMS) film as shown at Fig. 2. Polysiloxane is hydrophobic material with excellent thermal stability (Thermal resistance 250˚C, Relative Thermal Index - RTI is 150˚C) and good resistance to ultraviolet radiation.

We have developed a new PV panel renovation process [1] that include not only on-site thin 0.1 mm PDMS film deposition technology but also a comprehensive on-site PV panel diagnosis, including measurements of ground impedance (Risol), delamination, and other factors, both before and after the protective film deposition. The two component PDMS has been deposited on site by spraying method, see Fig. 3.

Fig. 3. Picture of renovation polysiloxane film on back side of PV panel.

PV panels repaired by polysiloxane film was observed for period of 5 years. The real field (wet) PV panel ground impedance (Risol) was restored after renovation (repair) and remain nearly unchanged for period of 5 years [1].

The PV panel renovation have to be made within about one year after rapid decrease of Risol is observed. Until now 41 MWp of PV were successfully recycled by thin siloxane film.

Total renovation price of typical recent PV panel sized 2 square meters with peak power about ~440 W is 11 U$ (material, labor, transport…) while replacement cost of the same panel is about 116 U$ (material, labor, transport…). Where PV panel price is 88 U$ and 28 U$ are remaining expenses (labor, transport…) Therefore, for PV power plant owner (end user) PV panels renovation is very profitable solution.

It is important to calculate real expenses for new replacement panel. Recently price of new premium PV panels is about ~0.30U$/Wp, low cost PV panels price is about ~0.15 U$/Wp and average cost of new PV panels is about 0.20U$/Wp now (year 2023). But it could be difficult to buy the equivalent panels produced 4-12 years ago as these panels can be out of stock and out of production lines. It is possible to arrange customized production (if required volumes are big enough) but anyway practical experience shows that price of such old design panels is usually very high. Prices like 0.3-0.7 U$/Wp are not unusual. So the 440 Wp PV panel price could be up to 300 U$ if the production would be restarted after 4-12 years.

The complete PV power plant renovation/repair cost is 3.5 % of the new PV plant price only.

PV panels renovation process pay-back time is about 6 months.

A scheme indicating difference between PV power plant owner profit and servicing expenses shows Fig. 4.

Fig. 4. Comparison between PV power plant owners profit and service expenses

From the business point of view the short (3-12 years) PV panel lifetime could be interesting for several entities. Just for instance short 3-12 years PV panel lifetime enables to arrange 2-9 loans instead of one within 30 years period. The International Energy Agency (IEA) evaluated total PV panel replacement in 10 year periods [6].

4 Conclusion

Brief analysis of the recent PV panel design shows that both quality and quantity of PV panel encapsulating materials has been substantially reduced within last 25 years. The real field PV panel lifetime was decreased to 3-12 years in demanding/tropical climate. The PV panel manufacturers should pay highest attention to quality of PV panel design. Innovative renovation technology was developed to prolong PV panel real field lifetime.

The proposed technology for on-site upgrading of solar PV modules is approximately 11 times more cost-effective than replacing the entire. The PDMS coating is stable for more than 5 years of exposure and allowed to restore the electrical insulation properties of the modules. Therefore, for PV power plant owner (end user) PV panels renovation is good and profitable solution. PV power plant owners should perform PV power plant monitoring very frequently to indicate beginning of PV panel degradation process in time.

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