Microfractures in Solar Modules: Causes, Detection and Consequences

The significant growth of the Australian residential solar energy industry over the last 5 years (APVI, 2014) has focussed attention on module quality and performance, as well as installation and safety standards.

It is critical for the industry to maintain high standards so that not only are solar photovoltaic (PV) systems safe, but also customers receive maximum benefit from their solar PV systems in terms of energy output and system lifetime.

There are national and international compliance requirements for solar modules installed in Australia. Under these standards, current requirements for solar modules relate to electrical safety, design qualification and type approval. The Clean Energy Council (CEC) maintains a database of compliant solar modules. (CEC, 2014). Over the life of a solar module, certain operational defects may develop. Microfractures represent one of these possible faults.

What are Microfractures?

Microfractures, also known as microcracks, represent a form of solar cell degradation. As the name suggests, microfractures are small cracks that can appear in solar cells. Micro-fracture length can vary; some span the whole cell, whereas others appear in only small sections of a cell. Microfractures can affect both energy output and system lifetime of a solar PV system.

What are the Causes of Microfractures?

Microfractures are typically caused either by excessive mechanical stress being applied to solar modules or by manufacturing defects. Excessive mechanical stress can usually be attributed to environmental conditions or to mechanical damage caused during the supply chain and logistics process or the PV system installation. Manufacturing defects can usually be attributed to poor quality or process control.

The environmental conditions that can cause microfractures in solar PV systems include:

- Thermal cycling (variation of temperature between night and day).
- Humidity and freezing.
- Cyclic (or dynamic) pressure loads and wind loading.
- Heavy snowfall.
- Hail.

Mechanical stress in the supply chain and logistics process can be caused by:

- Incorrect packaging.
- Unsuitable transportation methods.
- Incorrect handling techniques.

During the installation of a solar PV system, mechanical stress can be caused by:

- Stepping on modules or resting other equipment on modules.
- Bumping or dropping modules as they are lifted onto the roof.
- Installation on a non-planar surface, which may cause twisting of the mounting frame and place stress on the module.

“Microfracture length can vary; some span the whole cell, whereas others appear in only small sections of a cell.”

Note: To avoid damage, weight should not be applied on to a module. If weight being applied to a module is unavoidable, it should be applied on the frame of the module to reduce the risk of damage. If both of these options are unavailable, the weight should be applied to the middle of the module to spread the weight evenly over the module.

How are Microfractures Detected?

According to AS/NSZ 5033:2014 (Appendix C, Table C1), modules should be checked annually for visual defects, such as fractures, browning, moisture penetration and frame corrosion. One visual indicator that microfractures are present is the discolouration of the module surface, or 'snail trails', although this does not always occur. Figure 1 shows an example of this discolouration on solar cells. Microfractures themselves cannot be identified by the naked eye.

Figure 1: *Example of module discolouration or 'snail trails' on modules.*

Electroluminescence (EL) testing is used to identify microfractures in solar modules. EL testing can detect the non-visible light emitted when current is passed through a solar cell. The light is captured by a charge-coupled device (CCD) camera, which is sensitive to a range of wavelengths.

> ***"modules that have microfractures can still meet the warranted power over the module lifetime, so rejecting every module that contains a microfracture is not necessary."***

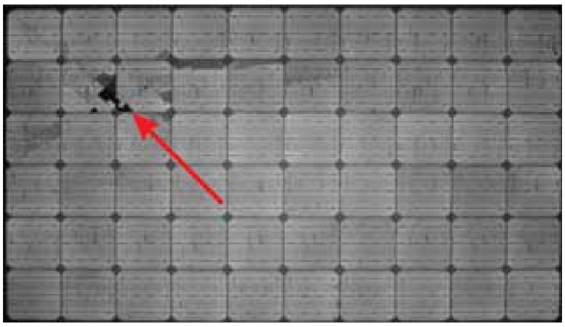

Figure 2: *Example of EL testing on a damaged module. Note the extreme case of microfracture in the cell with the black section. (Source: Evans* et al. *2014)*

The information gathered from this test produces an image, which can provide evidence of any faults or variations within a cell, including microfractures (Evans *et al.* 2014). Figure 2 shows an example of an EL image showing several microfractures, one of which is extreme.

Although it is not required by the CEC, most manufacturers will perform EL testing on a selection of their manufactured modules. Some manufacturers will even perform EL testing on all of their manufactured modules.

What are the Consequences of Microfractures?

Microfractures have the potential to create an electrical separation, resulting in inactive cell parts; however, quantifying the power loss caused by this is difficult. Recognising that microfractures can have different effects, Kontges *et al.* (2010) attempted to quantify the impact that microfractures have on module power output. They showed that modules that have microfractures can still meet the warranted power over the module lifetime, so rejecting every module that contains a microfracture is not necessary.

It was determined that losses of up to 2.5% can be experienced in a module with a large number of cracks that do not isolate parts of the cell. Larger losses can be experienced for a module with microfractures that do isolate parts of the cell. Microfractures also have the potential to produce hot spots. These occur when the internal resistance of the damaged cell rises and causes an increase in cell temperature as current passes through. Hot spots can cause further damage to a cell.

How do I Fix Microfractures?

Microfractures occur within cells and cannot be fixed without replacing the module. Care should be taken in determining whether the cracks are severely affecting the system performance, as it is uneconomical to replace well-performing modules.

For installers who are looking for a module supplier, the best way to avoid microfractures is to ensure that the supplier has the following:

- A well-defined supply chain.
- A warranty program that guarantees consumer confidence.
- A testing procedure that ensures each individual module receives EL testing.
- A strong reputation.

New customers should consider implementing active monitoring into their system; this can be at a module level, a multiple module level or a string level. Module-level data can pinpoint a power loss to an individual module, whereas string-level data can pinpoint a power loss to a whole string. Although module-level active monitoring is more accurate, it is more expensive than string-level active monitoring. There are several solar monitoring services that can be used to ensure that the solar PV system is performing as expected. New customers should also select a CEC-accredited installer with a good reputation. This installer must follow all Australian Standards and manufacturers' installation guidelines.

For system owners with active monitoring who are concerned that their solar PV system is affected by microfractures, an analysis of the data will show if the system is underperforming. These data can be used as evidence to claim warranty on the module. Owners can contact their installer or refer to their warranty documentation for more information.

For system owners who are concerned that their system is being affected by microfractures and who do not have active monitoring installed, retrofitting active monitoring should be considered, so that data can be collected. Other checks, such as I–V curve sweeping or thermal imaging, can also be done to find the problem.

> *"Module-level data can pinpoint a power loss to an individual module, whereas string-level data can pinpoint a power loss to a whole string."*

Along with all other recommended operation and maintenance procedures, all system owners should visually check their solar PV system annually (AS/NZS 5033:2014 Table C1). System owners could also consider an operations and maintenance service plan, under which qualified personnel come and service the solar PV system.

References

APVI. (2014, November). Australian PV market since April 2001. Retrieved March 2015, from http://pv-map.apvi.org.au/analyses

Berghold, J., *et al.* (2012). Electrochemical corrosion in solar cells. Proc. Of 27th EUPVSEC.

CEC. (2014). Modules. Retrieved March 2015, from https://www.solaraccreditation.com.au/products/modules.html

Evans, R., *et al.* (2014). Interpreting module EL images for quality control. Sydney, NSW, Australia: Suntech R&D Australia.

Intego. (2015). Wafers. Retrieved March 25, 2015, from http://www.intego.de/en/wafer

Kontges, M., *et al.* (2010). Quantifying The risk of power loss in PV modules due to micro cracks. Emmerthal, Germany: ISFH.

GSES welcomes feedback on technical papers and other resources available on www.gses.com.au, please contact GSES by email at info@gses.com.au or by telephone on 1300 265 525.