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Addressing Potential-induced Degradation of Field-installed PV Modules by Reducing Surface Conductivity

Khuram Shahzad\textsuperscript{a}, Muhammad Shoaib Khalid\textsuperscript{a}, Ahmad Amin\textsuperscript{a}, Kiran Israr\textsuperscript{a}, Rahmanullah Khan\textsuperscript{a}, Jaewon Oh\textsuperscript{b}, Sai Tatapudi\textsuperscript{b}, Govinda Samy Tamizhmani*\textsuperscript{b}

\textsuperscript{a}U.S. Pakistan Center for Advanced Studies in Energy, UET Peshawar, Pakistan
\textsuperscript{b}Arizona State University Photovoltaic Reliability Laboratory (ASU-PRL), Mesa, AZ, USA 85212

ABSTRACT

Potential-induced degradation (PID) has been one of the critical reliability issues in solar photovoltaic (PV) industry last several years. There are several PID mechanisms, but most well-known failure mechanism is the junction shunting, called PID-s. Cell p-n junction is shunted by sodium ion migration from PV module glass, which is due to leakage current caused by high potential difference between solar cell and aluminum frame of the module. Various methods preventing or reducing PID-s have been developed and used by the PV industry; however, those methods can be applied only at the manufacturing plants. We present a method of suppressing or preventing PID by interrupting surface conductivity of the glass, which can be applied to the field installed PV modules. In our previous study, we chose flexible Corning Willow Glass strips with ionomer adhesive to interrupt the surface conductivity of one-cell PV modules and multi-cell commercial PV modules. By applying the flexible Corning Willow Glass strips on the glass surface close to the frame inner edges, we experimentally demonstrated that PID-s can be practically eliminated in the full size commercial modules. In the current study, we investigated the surface conductivity interrupting technique by applying hydrophobic materials (instead of Corning Willow Glass) on the glass surface close to the inner edges of the frame. The module without any hydrophobic material suffered with 29\% of power loss after the PID stress test whereas the module with hydrophobic material suffered with only 15\% of power loss after the PID stress test. The current investigation indicates that the PID degradation can be significantly reduced using the hydrophobic materials but not eliminated as observed with the flexible Corning Willow Glass.

Keywords: Potential induced degradation, PID, photovoltaics, PV modules, reliability, durability

1. INTRODUCTION

In this fast growing world, photovoltaic (PV) system is becoming more and more popular to generate the electricity, and many large-scale PV power plants have been built around the world. One of serious reliability/durability issues which have been observed in the large-scale PV power plants is the potential-induced degradation (PID)\textsuperscript{1}. The PV power plants are built by connecting the PV modules in a series string to increase the system voltage up to 1500 Vdc. Due to the high voltage across the string, it is necessary to ground all the metallic frames of the PV modules to prevent the humans from electric shock. The frame grounding leads to a high potential difference between the cell and frame in the individual strings. PID mechanism is caused by this high potential difference resulting in leakage current between the PV solar cell and module frame, which could have a negative impact on PV modules and its long-term performance\textsuperscript{1}.

PID susceptibility of PV modules are not required to be tested as per the previous/current IEC 61215 standard\textsuperscript{2}. A new standard, IEC TS 62804-1\textsuperscript{1}, has recently been developed to test the PID modules for their PID susceptibility. In addition to this PID standard, the researchers have developed several PID prevention methods to address the PID issue. The PID can be avoided using system level, module level, and/or cell level mitigation approaches\textsuperscript{1}. New PV modules manufactured and sold after 2010 have typically shown no PID degradation since PID-resistant cells or PID-resistant PV module materials have been used at the manufacturing stage (cell level and module level). In power plant, however, a tremendous number of PV modules installed before 2010 and some of the modules installed after 2010 are suffering or
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3. RESULTS AND DISCUSSION

3.1 Performance analysis

Since the 3M tapes covered a part of the edge cells, some short-circuit current loss, causing Pmax loss, was observed after applying the tape as shown in Table 1. The Pmax of module M2 and M3 is reduced by 0.8% and 0.5%, respectively i.e. the M2 was slightly more affected than the M3 as shown in Table 1. It is because 3M weather resistant film 838 tape was translucent while 3M PTFE extruded film 5490 tape was transparent. This effect can be eliminated by using narrow width tape not extending over the cell area. Table 2 shows the pre- and post-stress test results of all three modules. Reference module M1 showed large power drop of 29% of Pmax whereas module M2 reduced to 15% of Pmax and M3 reduced to 17% of Pmax after PID stress. These results indicate that the 3M weather resistant film 838 tape is slightly more effective in reducing the PID effect.

Table 1. Performance analysis of module M2 and M3 before and after applying the tape

<table>
<thead>
<tr>
<th>Module</th>
<th>Condition</th>
<th>Isc</th>
<th>Voc</th>
<th>Imp</th>
<th>Vmp</th>
<th>FF</th>
<th>Pmax</th>
<th>Pmax loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>V</td>
<td>A</td>
<td>V</td>
<td>%</td>
<td>W</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>M2</td>
<td>Without Tape</td>
<td>7.91</td>
<td>45.1</td>
<td>7.44</td>
<td>37.2</td>
<td>77.6</td>
<td>277.0</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>With tape</td>
<td>8.30</td>
<td>44.9</td>
<td>7.32</td>
<td>37.5</td>
<td>73.7</td>
<td>274.8</td>
<td></td>
</tr>
<tr>
<td>M3</td>
<td>Without Tape</td>
<td>8.51</td>
<td>45.6</td>
<td>7.93</td>
<td>36.6</td>
<td>74.8</td>
<td>290.1</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>With tape</td>
<td>8.71</td>
<td>44.9</td>
<td>7.93</td>
<td>36.4</td>
<td>73.8</td>
<td>288.5</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Module M3 with 3M PTFE extruded transparent tape 5490 applied at the inner edges of the frame. Red dotted lines indicate the area where the hydrophobic tape was applied.
It is observed that Pmax loss due to PID stress is mainly caused by module failures (M2 and M3) that experienced PID analysis of module M1 (PID testing, Altho Glass applied which did not have the hydrophobic tape. The in commercial low Glass.}

**Table 2.**

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voc (V)</td>
<td>45.2</td>
<td>42.9</td>
<td>45.1</td>
<td>44.9</td>
<td>45.6</td>
<td>44.5</td>
</tr>
<tr>
<td>I (A)</td>
<td>8.5</td>
<td>8.4</td>
<td>8.4</td>
<td>8.5</td>
<td>8.5</td>
<td>8.5</td>
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<tr>
<td>FF (%)</td>
<td>36.8</td>
<td>29.9</td>
<td>37.2</td>
<td>33.6</td>
<td>36.6</td>
<td>33.0</td>
</tr>
<tr>
<td>Pmax (%)</td>
<td>29%</td>
<td>15%</td>
<td>17%</td>
<td>29%</td>
<td>15%</td>
<td>17%</td>
</tr>
</tbody>
</table>

**Figure 3.**

Module M1 before and after PID (f) Module M2 after PID (c) Module M3 before and after PID (a) Module M2 before PID (e) Module M3 after PID (b) Module M1 after PID (d)
3.2 Electroluminescence module M2 testing. After the modules (d) and (f), the volume resistance of the cells near the frame were much less than that found to be severely affected by PID compared to the conducting the PID stress testing. The activity of the modules was greatly reduced, and the inner edge of the PID affected cells were shunting, how the frame. Figure 4. The EL images before and after PID (a, b, c, d, e, f). Module M2 before PID (b) Module M3 after PID (c) Module M1 after PID stress testing are shown in Figure 4. The EL images before and after PID stress testing. The EL images were in good condition before PID stress.
4. CONCLUSION

The 3M weather resistant 838 hydrophobic tape and 3M PTFE extruded 5490 hydrophobic tape were applied at the inner edges of the frames of modules M2 and M3. The control module (M1 without any tape) and the two tape-applied modules (M2 and M3) were subjected to the PID stress testing at –600V between shorted output terminal and frame at 60°C / 85%RH. The PID shunting has mainly been observed in the cells near the aluminum frame due to the close proximity of these cells to the frame. The I-V and EL showed that all three modules were affected by PID regardless of application of edge disruption technique, though the 3M tape applied PV modules showed remarkably much less PID loss than the module without the tape. It was noticed that the surface current interruption technique using the 3M hydrophobic tapes did reduce the PID loss, but the technique was not as effective as Corning Willow Glass strips that was reported in our previous study5.

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