ACCURATE POWER MEASUREMENTS OF HIGH CAPACITANCE PV MODULES WITH SHORT PULSE SIMULATORS IN A SINGLE FLASH

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ABSTRACT: A method for measuring accurately and rapidly the current-voltage characteristics of high-capacitance photovoltaic devices using pulse sunlight simulators is detailed. The data acquisition is performed in a single light flash, whose duration can be as short as milliseconds. The method allows sufficient time for every individual IV data point to relax from capacitive effects, while employing efficient time management to the applied measurement load to achieve full IV tracking in a single flash of light. The method, which is called Dynamic IV (t-IV), was validated in an experiment, which examined three different types of commercially available high-capacitance PV modules. The results of the Dynamic IV were compared against steady-state IV measurements of each module showing agreement with deviations largely overlapping within the limits of the measurement repeatability and not exceeding 0.2% on maximum power output.

DYNAMIC IV METHODOLOGY

The time required to measure a single IV data point free of capacitive artefacts is related to the capacitance of the device and its applied load. As long as the irradiance level is maintained constant, the required time is approximately increasing proportionally to the capacitance change of the device caused by the applied load.

VALIDATION OF DYNAMIC IV MEASUREMENTS IN LABORATORIAL ENVIRONMENT

The performance of three commercially available modules was measured under standard test conditions (STC) using two different approaches: dynamic IV and multiflash IV. The results of the methods are compared to examine the accuracy of t-IV measurements. The selected modules are listed in Table 1 in alphabetical order. The test samples will be referred to in this work as modules A, B and C in an order that does not necessarily correspond to their order of appearance in Table 1.

APPLICATION TO PRODUCTION LINE MEASUREMENTS

In order to evaluate the measurement accuracy of dynamic IV measurements under industrial conditions an experiment was conducted. Initially, the t-IV profile of a reference module was analysed in laboratorial conditions. The resulting profile was then used as a guideline to rate different test samples of the same module type, but different class. The results of dynamic IV were compared with the result of multiflash method.

CONCLUSIONS

A method to perform accurate power measurements of high-capacitance modules with pulse simulators in single flash was presented. Laboratorial calibration was shown to be achievable with an additional contribution to the measurement uncertainty of ±0.3%. The second gained encouraging results, which indicated that the added contribution to measurement uncertainty can be kept as low as ±0.6%, if appropriate quality assurance is in place. However, the implementation of dynamic IV measurements for industrial rating will require further research.

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Table 1

<table>
<thead>
<tr>
<th>PV Module Manufacturer</th>
<th>Cell Type</th>
<th>Cell Intercon. Ser. / Par.</th>
<th>Module Rating of Unsorted Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanyo Electric, Co. Ltd</td>
<td>HIT®</td>
<td>72s/1p</td>
<td>Module Rating of Unsorted Classes</td>
</tr>
<tr>
<td>SunPower Corporation</td>
<td>c-Si, back-contact</td>
<td>72s/1p</td>
<td>Module Rating of Unsorted Classes</td>
</tr>
<tr>
<td>Yingli Energy, Co., Ltd</td>
<td>c-Si, n-type</td>
<td>60s/1p</td>
<td>Module Rating of Unsorted Classes</td>
</tr>
</tbody>
</table>

Figure 1: Comparison of the IV characteristics of a high-capacitive module between different measurement techniques. The blue data points represent the dynamic IV curve, performed in 10ms, showing agreement with the steady-state characteristics.

Figure 2: The sampled IV data points, which are free of measurement artefacts, are highlighted with a triangle. The measurement time increases almost exponentially with voltage to compensate for transient errors.

Figure 3: The variation of PV module capacitance is shown for two commercially available BCT and HJT modules. The dotted points correspond to the device capacitance extracted from t-IV measurements for the BCT and HJT modules.

Figure 4: The dynamic behaviour of PV modules can be modelled. The characteristics of one particular point have been enlarged to illustrate the magnitude of the deviations.

Figure 5: Applied load distributions for two modules showing moderate (mesh A) and high (mesh B) capacitive behaviour.

Figure 6: An example of application of dynamic IV algorithm to predict the steady-state IV characteristics.