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SHADE PERFORMANCE OF A NOVEL HIGH-VOLTAGE BACK-CONTACT MODULE

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ABSTRACT: In this paper we present ECN's new high-voltage module concept which is based on MWT back-contact technology, and test its performance under shadow conditions. Controlled realistic shading tests were performed for three shade cases that are typical for PV applications in the built environment (a pole shade, a tree shade and a dormer shade). The relative power output (shaded over normal) of the high-voltage module was compared to that of a conventional three string, 60-cell module. The new high-voltage module significantly outperformed the conventional module: its shade performance was 1.1 to 4.2 times better, and its shade linearity was around 80%.
Keywords: Shading, Back Contact, PV Module, High Voltage

1 INTRODUCTION

Conventional PV modules are limited by their shade nonlinearity and by ohmic losses due to high currents. ECN has developed a high-voltage low-current module concept for better performance under shadow conditions. The concept, which is based on Metal Wrap Through back-contact technology, uses groups of sixteen MWT mini-cells. Each group has its own bypass diode and operates as a shade-independent unit. The high voltage enables simple, lean and efficient inverter designs, making it possible to reduce BoS costs. The low current allows for use of small bypass diodes which can be integrated in the PV laminate. Also, the copper interconnection material in the backsheet of the module can be reduced 10-fold due to the low current.

Performance under shading is a key issue for PV applications in the built environment, because shade is inevitable in many practical cases and at the same time power loss is far from linear with shaded area for many module technologies. We try to solve this issue by embedding shade robustness in the module laminate: in our high-voltage module concept, groups of mini-cells each protected by a small bypass diode function as shade-independent units. Other solutions include the application of power optimisers and micro-inverters to optimise yield and make modules independent from others.

The purpose of this study is to quantify the shade performance of a high voltage back-contact module relative to that of a conventional (3-string, 60-cell) module.

2 METHODS

2.1 High-voltage module

The high-voltage module concept is based on Metal Wrap Through (MWT) back-contact technology [1]. MWT cells were divided into smaller pieces (mini-cells). The mini-cells were connected in groups where each group has its own bypass diode. These groups operate as independent units under shade. The low current allows for use of small bypass diodes which are integrated in the PV laminate. Prototype modules (8x8 mini-cells) were fabricated [2] and used for the shade performance assessment, see Fig.1.

Figure 1: High-voltage 8x8 prototype module

2.2 Measurements

We tested shade performance of a HV and a conventional 6x10 cell module with a Pasan flash tester at standard test conditions (STC). The HV prototype module, having dimensions equivalent to 2x2 conventional cells, was flashed at 15 distinct positions on the 6x10 cell grid using a multi-flash approach (Fig. 2). This multi-position measurement allowed us to calculate the IV curve of a full-scale HV module.

Three partial shade cases were selected that are relevant for building integrated and building applied PV applications: a pole shade, a tree shade, and a dormer shade. The set-ups to test these shades are depicted in Fig. 3. The pole shade was a hard shade which covered all three strings of the conventional module. For the tree shade, the leafs partially covered 42% of the module area. The dormer shade was implemented with a gaze, which cast a dark (80%), slantwise shadow on the module.

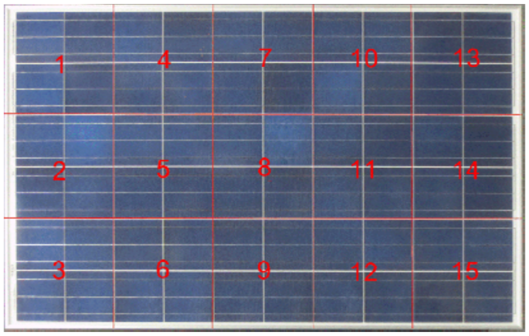

Figure 2: Schematic drawing showing the 15 flash positions of the high-voltage (2x2 cell equivalent) prototype module on the 6x10 cell conventional module area

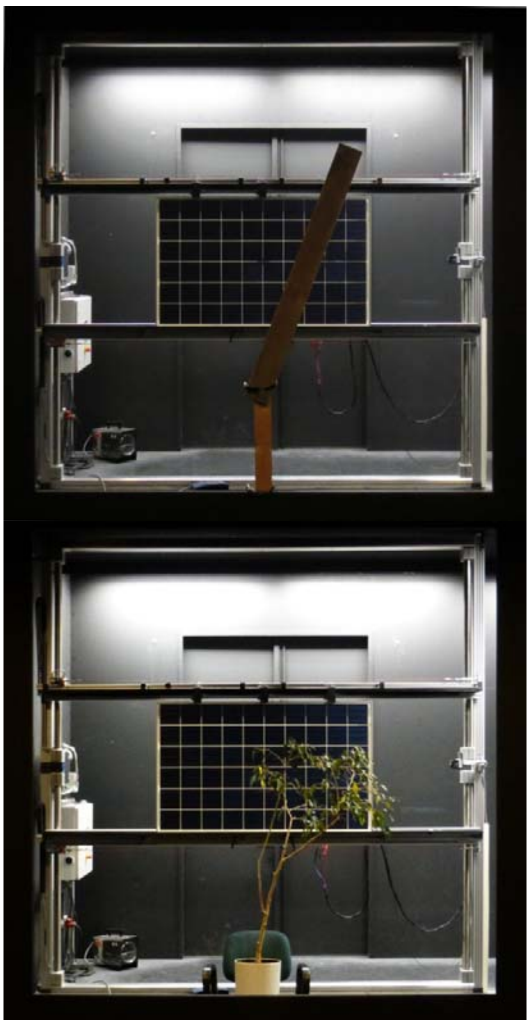

Figure 3: Measurement set-up for the three shade cases that were tested: a pole shade (top), a tree shade (middle), and a dormer shade (bottom)

2.3 Evaluation parameters

Two evaluation parameters were used for the performance evaluation: shade performance (SP) and shade linearity (SL).

Shade performance was defined as the ratio of MPP power under shadow and nominal MPP power at standard test conditions (STC, unshaded):

$$\mathrm{SP} = \frac{P_{mpp\_shaded}}{P_{mpp\_stc}} \cdot 100\%$$

This performance indicator allows a direct comparison of two different module types exposed to the same shadow.

Shade linearity relates the power output under shade to that of an ideal, fully shade-linear module. Here, the contribution of each shaded sub-section is taken into account: for an unshaded section, we may expect 100% of its power output; for a shaded section, no output is possible; for a partially shaded section, the output power is proportional to the light intensity. Shade linearity was defined as:

$$\mathrm{SL} = \frac{P_{mpp\_shaded}}{P_{mpp\_stc} \cdot \sum_{n=1}^{N} a_i \cdot x_i} \cdot 100\%$$

where N is the number of module sections with distinct shading, a_i the area fraction of such a section ($a_i = A_i/A$) and x_i its light intensity ($x_i = X_i/X_{stc}$).

A perfect module has a shade linearity close to 100% for any shade case. Shade linearity 0 indicates that no power output was obtained in case a shade was applied.

3 RESULTS

Three shade cases were evaluated: a line shade, a tree shade, and a diagonal shade. The impact of these shades on the IV-curves of the conventional and the HV module is depicted in Figures 4-6. The IV-curves demonstrate the effective operation of bypass diodes combined with small groups of mini-cells. This leads to a better shade linearity and shade performance for the HV module.

The shade performance and shade linearity results are given in Table I and Table II. Overall, the shade performance was 1.1 to 4.2 times better for the HV module than for the conventional module (Table I). As expected, the biggest difference in shade performance was observed for a dark shade that hits three strings in a conventional module (e.g. the pole shade).

The shade linearity was around 80% for the HV module, whereas it ranged from 20 to 66% for the conventional module (Table II).

Table I: Shade performance

	Conventional Module	High-Voltage Module	HV/ Conv
Pole shade	17%	73%	4.2
Tree shade	53%	60%	1.1
Dormer shade	26%	57%	2.2

Table II: Shade linearity

	Conventional Module	High-Voltage Module
Pole shade	20%	83%
Tree shade	66%	75%
Dormer shade	38%	81%

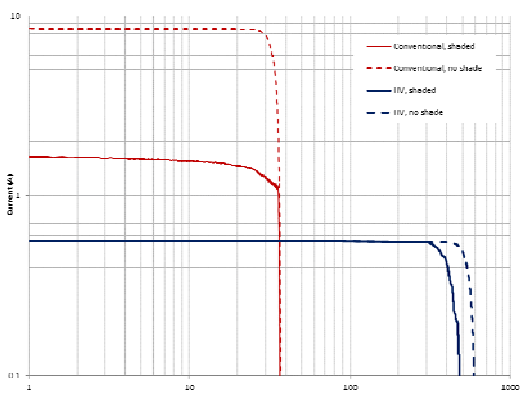

Figure 4: Impact of the pole shade on IV-curves of conventional (red lines) and HV (blue lines) modules

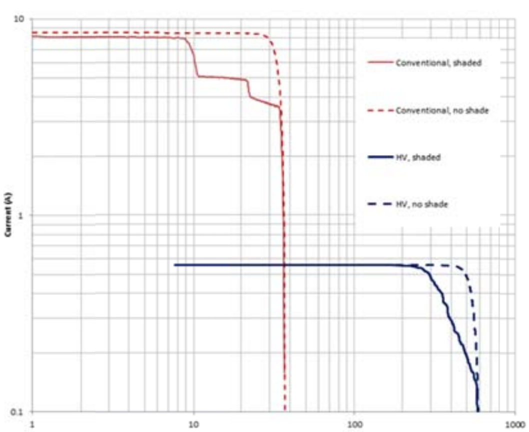

Figure 5: Impact of the tree shade on IV-curves of conventional (red lines) and HV (blue lines) modules

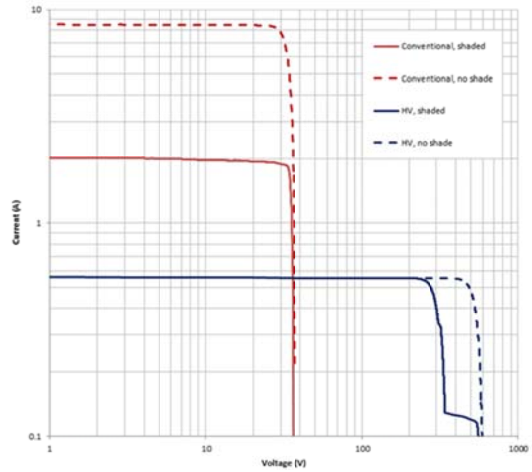

Figure 6: Impact of the dormer shade on IV-curves of conventional (red lines) and HV (blue lines) modules

4 CONCLUSIONS

In short, we present a new module concept which is intrinsically shade robust with the advantages of a high-voltage and low-current power output. Overall the shade linearity of the HV module was around 80%, and its shade performance was 1.1 - 4.2× higher than conventional for the three shade cases tested.

5 REFERENCES

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