ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

Outdoor non-contact measurement of pseudo I-V curves of solar cells in a module

Raghavi Bhoopathy, Oliver Kunz, Robert Dumbrell, Thorsten Trupke, Ziv Hameiri

School of Photovoltaic and Renewable Energy Engineering, University of New South Wales (UNSW), Sydney NSW 2052, Australia
E-mail: raghaviprofessional@gmail.com

Current-voltage (I-V) measurements of a solar cell or of a photovoltaic (PV) module are critical to determine the overall power output of a PV system whose degradation rate has a critical impact on the levelized cost of electricity and on the bankability of PV projects [1]. Currently existing characterization techniques, such as infra-red (IR) thermography [2], ultra-violet (UV) fluorescence [3], electro-luminescence (EL) [4]–[6] and photoluminescence (PL) [7] imaging have proven to be helpful in identifying performance-limiting module faults. However, all these characterization techniques fail to provide quantitative information regarding the nature of each fault. In order to investigate the cause of these faults, additional characterization techniques must be developed. I-V measurements can provide quantitative information regarding various performance limiting faults in solar cells. In many cases they can be used to identify the fault type and its typical causes. Yet, in the case of a PV module, only the terminal characteristics are obtained using conventional methods. Obtaining the I-V parameters of an *individual* cell within a module can be very useful, however, such information is not easily accessible in modules installed in the field since (1) the solar cells are embedded in a laminated module rendering their contacts inaccessible, and (2) the modules are connected to a solar array that is operating during daylight conditions.

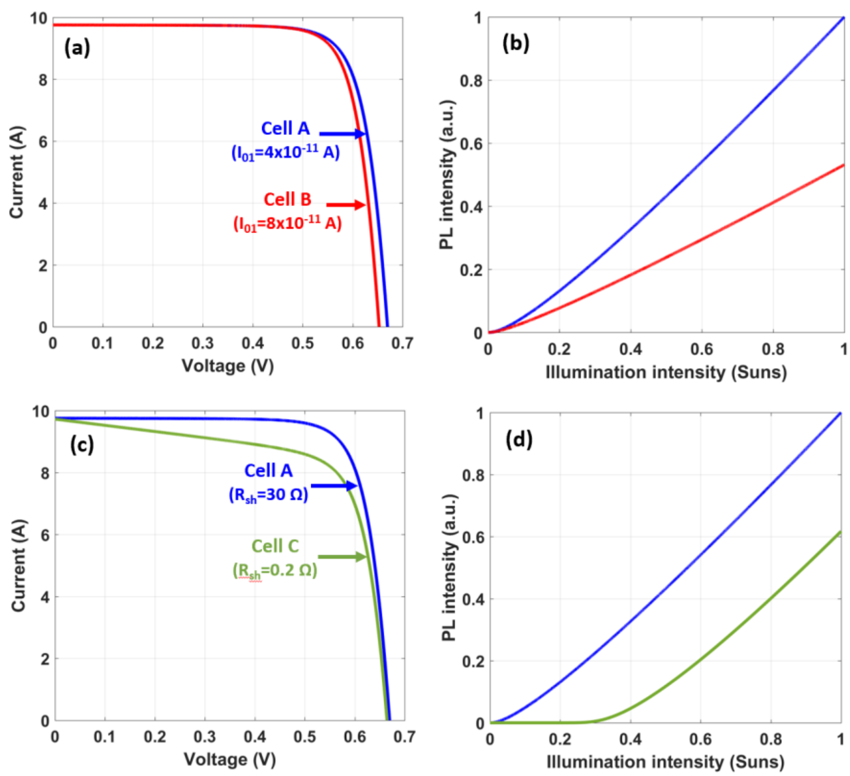

Figure 1. Comparison of the I-V curve of a typical cell (Cell A) with simulated I-V curve of a cell with increased (a) base recombination current (Cell B) and (c) shunt resistance (Cell C) along with the cells' PL (b and d) as a function of illumination.

In this study we demonstrate the application of the Suns-PL technique [8] to non-contact extraction of the pseudo I-V characteristics of solar cells that are part of a larger PV system, operating under full daylight illumination (field operating conditions).

During Suns-PL measurements, solar cells are irradiated with a temporally changing illumination using a specially developed experimental set-up. The set-up is placed on top of the tested cell to simultaneously measure both the illumination and the PL intensity. The PL signal as a function of illumination intensity reveals the different faults, such as shunting and increased base recombination current, as shown in Figure 1. Since the illumination intensity is a measure of the current generation and the PL signal is a measure of the device voltage, the cell's characteristic I-V relationship can be obtained as an pseudo I-V curve to further understand the fault in detail.

The technical considerations of this method and its aplication in the field during daylight hours will be presented at the conference. The obtained pseudo I-V curves will allow identification of various faults in individual cells in a photovoltaic module. The proposed method can be easily applied to inspect large solar fields in a very short time with the help of unmanned aerial vehicles and artificial intelligence.

References

[1] L. Tinker, R. Jones-albertus, and I. Ave, "Emerging PV Technologies : the path to market competitiveness," *IEEE 43rd Photovolt. Spec. Conf.*, pp. 3471–3474, 2016.
[2] J. A. Tsanakas, L. Ha, and C. Buerhop, "Faults and infrared thermographic diagnosis in operating c-Si photovoltaic modules: A review of research and future challenges," *Renew. Sustain. Energy Rev.*, vol. 62, pp. 695–709, 2016.
[3] A. Morlier, M. Siebert, I. Kunze, G. Mathiak, and M. Kontges, "Detecting photovoltaic module failures in the field during daytime with ultraviolet fluorescence module inspection," in *IEEE Journal of Photovoltaics*, 2017, vol. 7, pp. 1710–1716.
[4] C. Y. Peng, S. Y. Wen, Z. J. Ji, and C. P. Huang, "Non-destructive displaying defects for luminescence image of photovoltaic panel arrays," in *International Conference on Advanced Robotics and Intelligent Systems*, 2015, pp. 1–4.
[5] A. Gisele *et al.*, "Development of outdoor luminescence imaging for drone-based PV array inspection," in *44th IEEE Photovoltaic Specialists Conference*, 2017, pp. 2682–2687.
[6] L. Stoicescu, M. Reuter, and J. Werner, "Daysy: luminescence imaging of PV modules in daylight," in *29th European Photovoltaics Solar Energy Conference and Exhibition*, 2014, pp. 2553–2554.
[7] I. Zafirovska, M. K. Juhl, J. W. Weber, O. Kunz, and T. Trupke, "Module inspection using line scanning photoluminescence imaging," in *32nd European Photovoltaic Solar Energy Conference and Exhibition*, 2013, pp. 1826–1829.
[8] T. Trupke, R. A. Bardos, M. D. Abbott, and J. E. Cotter, "Suns-photoluminescence: Contactless determination of current-voltage characteristics of silicon wafers," *Appl. Phys. Lett.*, vol. 87, no. 9, pp. 2005–2007, 2005.