I-V Curve Simulation of Curved PV Modules for Vehicle Integration under various irradiation conditions

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1. Introductive summary

Vehicle Integrated Photovoltaics (VIPV) are raising the interest among PV technologies by trying to implement curved modules in Electrical Vehicles (EV). Curved modules can adapt to the complex aesthetics of EV and increase their effective autonomy. As these implementations are recent, no performance prediction tools nor measurement methods are firmly established yet even though they are necessary as curved modules, by design, will always be subjected to inhomogeneous irradiances. We introduce here the results of a simulation model that can predict the behavior of curved modules under various lighting conditions such as indoor illumination with different PASAN sun simulator configurations or typical outdoor conditions.

2. Scientific relevance and innovation

Curved modules can yield extremely varying results depending on where and how they are used. A low sun elevation on curved modules placed horizontally will produce completely different behaviors compared to flat modules because of self-shading and cell irradiance mismatch. Also, the presence and the arrangements of bypass diodes add complexity to the system design. In these circumstances, a power rating method representative of final use appears extremely challenging. In this contribution, a power rating methodology using various configurations (lamp-module distance) of conventional PASAN flasher is investigated. We propose a normalized characterization methodology for curved modules, a possible path to standardized power ratings. The measurement standard should issue useful performance indicators, precise power ratings and meaningful energy predictions in standard VIPV operations. Our model aims at predicting and quantifying performances of arbitrary curved module topologies to help choosing the most adequate solution for use in EV applications, accounting for temperature and irradiance variation.

3. Aim and approach used

With our model, we study the impact on the module power rating of different factors such as its curvature, cell topology (string in parallel or series with arbitrary arrangements of bypass diodes, see Figure 1), the particular geometry of the incident light (here 4.8m and 8m PASAN flashers are considered), and different flashing conditions such as the module placement. The model is also capable of predicting energy yield under various outdoor conditions of illumination (direct and diffuse sunlight) considering the integration in a moving EV (Figure 2). Critical factors to VIPV such as temperature fluctuation, car and sun position and orientation were taken into account by using typical meteorological year (TMY) data sets with different geolocations (Figure 3). The model in our simulations for power rating prediction is now in a validation phase with a measurement campaign. We use a flexible module (Figure 4) fixed on a wooden structure with curvatures and compare the measured and predicted IV curves (Figure 5). The flexible module is specially designed to switch between different cells configurations and test all the aforementioned topologies.

4. Results and conclusions

Presently, we obtained the expected IV curves in different situations (with and without bypass diodes), including module rotation, temperature and irradiance variation and different topologies. The experimental results, yet to be obtained, on a PASAN tunnel flasher will be used to validate the model and will be presented during the conference. Our experimental configuration allows the variation of the module curvature as well as the cell arrangement. The impact of the flasher incident light angle will be evaluated and guidelines for the power assessment of curved modules will be proposed on that basis.

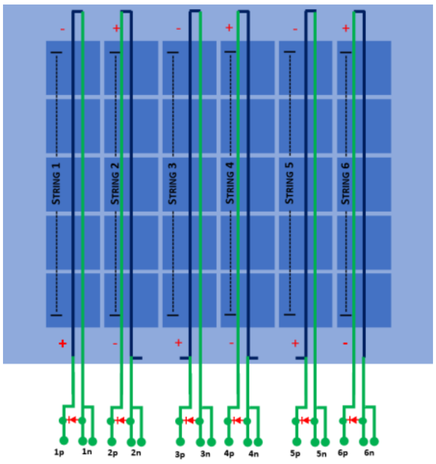

Figure 1 – Diagram of the flexible module with modulable topology. It is possible to connect the strings in various manners and use the bypass diodes if wanted.

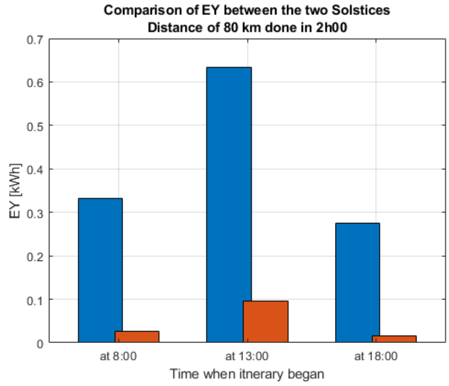

Figure 2 – Comparison of the energy yield of a curved estimated during a 2-hour itinerary starting in morning, noon, and evening conditions. Car location, sun and car orientation, and outdoor conditions were taken in account. The blue data is for the June solstice and the orange data is for the December solstice.

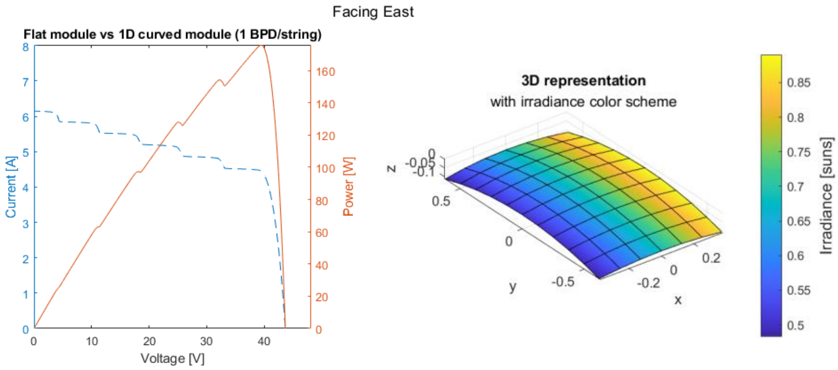

Figure 3 – 3D representation of an arbitrary VIPV (right) composed of 60 cells with 6 strings each bypassed with diodes. The IV and IP curves (left) depict the conditions when the car is facing east. The inhomogeneous irradiance shows how the bypass diodes create these staircase effects.

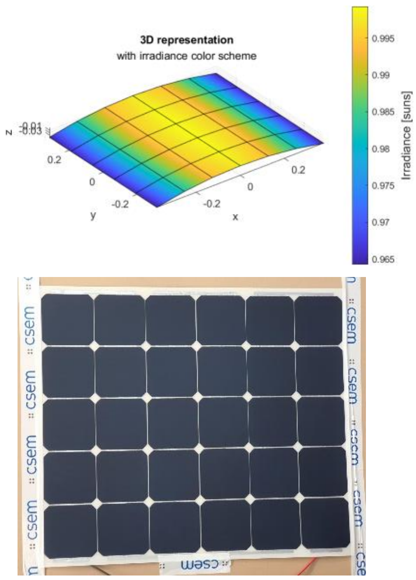

Figure 4 – Flexible module created to validate the simulation model. It is a 30 cells module with 6 strings of 5 cells each. Soon to be modified and to be configurable as explained in the abstract.

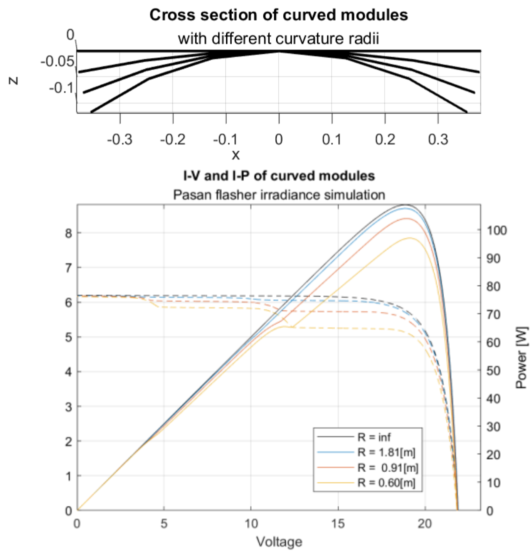

Figure 5 – Modules with different curvatures (upper image) with their corresponding IV and IP curves (lower image). The curvatures are given in the lower image in the correct order from top to bottom.