Quantification of Some Properties of the PV Panel - Converter Interface

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Abstract

The benefits of solar energy usage include clean and sustainable electricity to the world while the carbon foot-print of PV (photovoltaic) systems is decreasing every year. PV systems can provide clean power for large, as well as small, energy harvesting applications. They are already installed and generating energy around the world on individual homes, housing developments, offices and public buildings.
The optimal design of modern PV oriented power systems as part of the Smart Grid concept, however, may be accomplished only by proper modelling and simulation of entire PV – electronic power system. Our main interest was to search for application of dynamic modelling of the PV system. A large set of published results was consulted, and we came to a conclusion that no dynamic circuit modelling was exercised at all. In fact, under dynamic modelling of PV systems thermal transient analysis was understood.
Trying to establish some influence to the PV system design chain, in our recent proceedings [1], [2] we proved by simulation and measurements that the interface of the photovoltaic (PV) panel and the DC/DC converter is by no means a circuit with simple signals. Namely, as it is the case in the AC branch of the electricity distribution chain where the sinusoidal waveforms are distorted by nonlinear loads due to the commutations within the converter, the current, or better to say, energy taken from the PV panel, is not constant and has a pulse shaped waveform. As a consequence, the current, voltage, and power waveforms at the PV panel's output have an AC component that is to be identified and its effects should be studied. Usually that interface is equipped by an electrolytic capacitor of a large capacitance that is supposed to short-circuit the AC component of the interface voltage. Its AC current sinking capacities, however, were shown to be limited and the AC component was not eliminated. Furthermore, real capacitors exhibit series resistance and inductance that influence the resulting voltage at the basic and harmonic frequencies of the main switches within the converter. It is needless to say that all, the capacitance, inductance, and resistance of the electrolytic capacitor are strongly temperature dependent and subject of aging. Altogether, because of the alternating component of the PV-panel-output-voltage that comes from the converter, the PV-panel's working point is taken out of the maximum power point with high frequency and with amplitude that can reduce the output power.

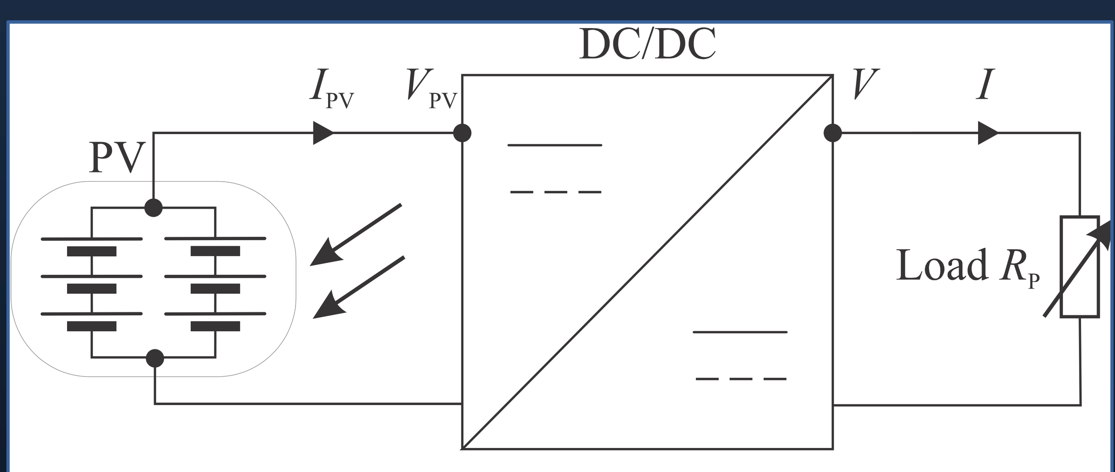

Figure 1. Representation of the PV system to load connection

Measurements

The characterization of the system depicted in Fig. 1 was performed using a PV panel consisting of 18 cells connected in two equal columns. The Mean Well NSD15-S [11] converter was used. Resistor denoted by was used as a variable load. Its lowest resistance values were limited by the modest driving capabilities of the DC/DC converter.

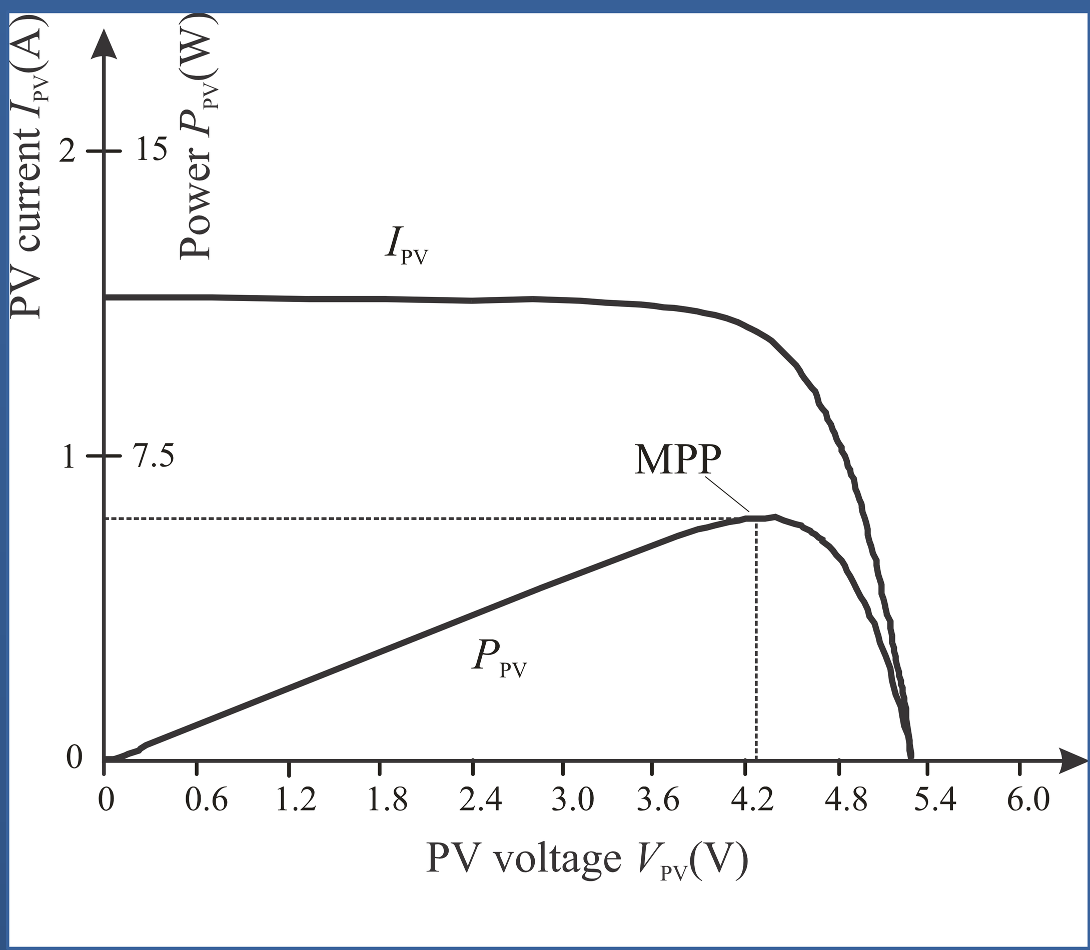

Figure 2. Measured PV current and power as a function of the voltage of a PV cell. MPP stands for Maximum Power Point

DC Characterization

The power/load dependence are depicted in Fig. 3. The measurements were undertaken at noon of the (sunny) April 20, 2013. The panel was positioned for best incident angle of the incoming light. The input voltage is practically independent of the load, while the input and the output power are decreased when the load resistance is raised. That, in a smaller scale, stands for the efficiency of the converter.

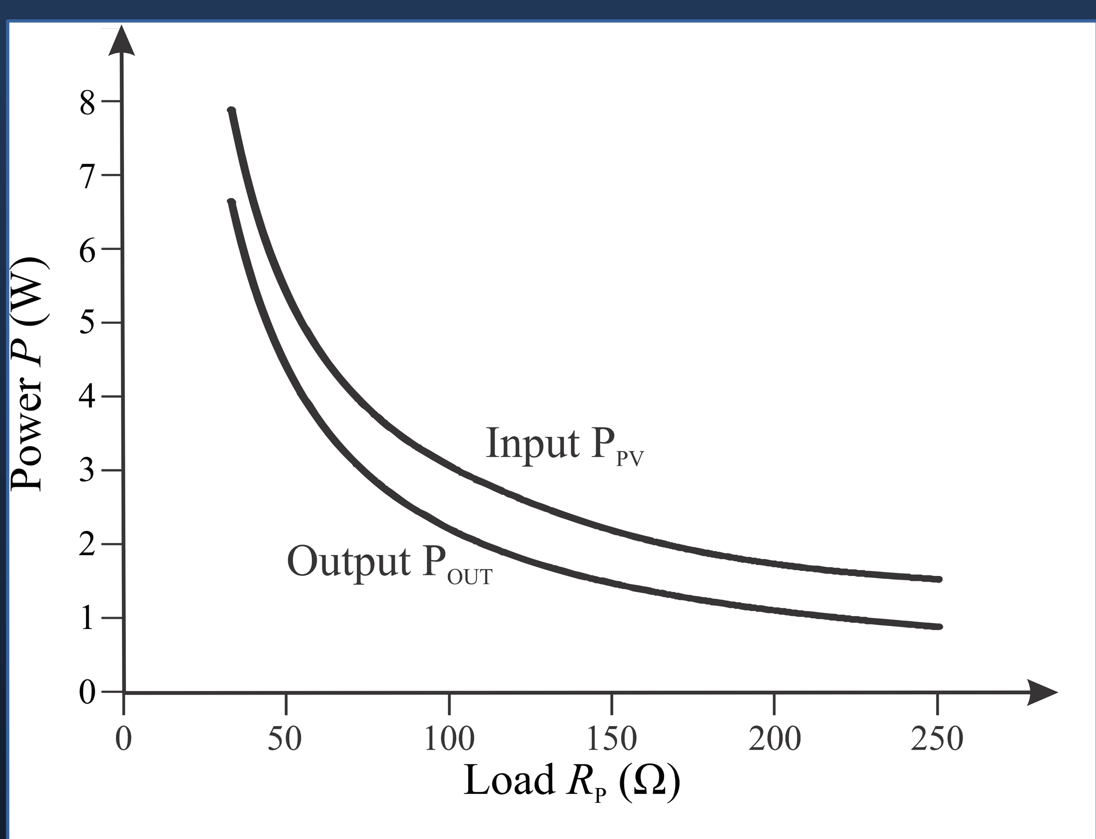

Figure 3. Input and output DC power of the converter as a function of the load to the system under full insolation

AC Characterization

The working conditions of the PV panel were out of the maximum power point which is depicted in Fig. 2. That can be recognized by inspection of Fig. 3 where the power delivered by the panel is denoted as "Input P_{PV}". It can be seen that the power is monotonically decreasing with the rise of the load resistance. The reason for that was the low driving capabilities of the convertor available to the authors. Otherwise lower values of would be used.
The fact of crucial importance for this proceeding is that when measurements with high insolation were done no alternating component of the panel's current and voltages was observed. That was in contrast to the expectations based on the results obtained by simulation (Fig. 4.).

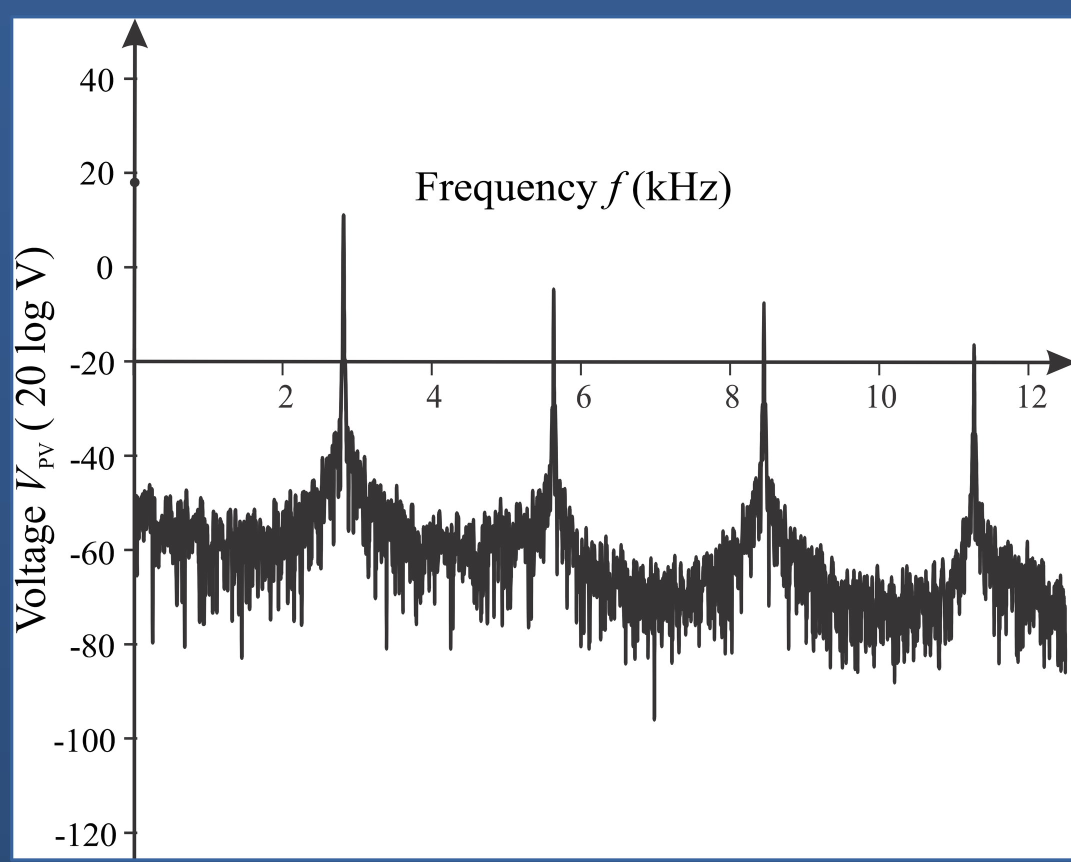

Figure 4. Spectrum of the PV panel's output and the inverter's input voltage as a function of frequency for measurement under cloudy weather, R_P=100Ω

Conclusion

The photovoltaic system being always built of a PV source (panel) and a converter (or inverter) has its own specific properties that are frequently overlooked leading to unrealistic designs. After characterizing the system by measurements for two different conditions (high and low illumination) we studied the PV panel – converter interface for which we supposed to have current containing non-negligible AC component. To quantify the properties of the interface we introduced several variables whose values were extracted by simulation.
We showed here that at the PV-converter interface the signal is far from DC, implying the dynamic properties of the PV side.

[1] Andrejević Stošović, M., Lukač, D., Litovski, V., "Realistic modeling and simulation of the PV system - converter interface", Proceedings of the 4th Small Systems Simulation Symposium, Niš, Serbia, 2012, ISBN 978-86-6125-059-0, pp. 28-32.
[2] Dimitrijević, M., Andrejević Stošović, M., Petrušić, Z., and Lukač, D., "Experimental Characterization of the PV Panel - Converter Interface", Proc. of the LVI Conf. of ETRAN, Zlatibor, ISBN 978-86-80509-67-9, Proc. on disc, Paper. No. EL4.3.

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