Passivity-based control of active and reactive power in single-phase PV inverters

Domingo Biel
Institute of Industrial and Control Engineering
Department of Electronic Engineering
Universitat Politecnica de Catalunya
Spain
Email: domingo.biel@upc.edu

Jacquelien Scherpen
Engineering and Technology Institute (ENTEG)
Faculty of Mathematics and Natural Sciences
University of Groningen
The Netherlands
Email: j.m.a.scherpen@rug.nl

1 Introduction

The increase of the number of PV installations has great impact on the electricity network, makes the grid more decentralized and the grid quality can be seriously affected. For this reason, nowadays some new functionalities are required for the PV systems in order to keep the grid (at least at the connection point of the PV system) in compliance with the quality standards. One of these new requirements is the control of the active and the reactive power that the inverter injects to the grid. The presented work applies passivity-based control to get the aforementioned control. This control has been successfully applied to power converters ([1], [2], among others) but not yet been for the control of the power in single-phase PV inverters.

2 Proposed passivity-based control

Figure 1 shows the scheme of the proposed control. The PV inverter is connected to a non-ideal grid (modelled by an impedance and an ideal sinusoidal source). The state equations (in averaged values) of the PV inverter are:

$$C\dot{z}_1 = -uz_2 + f_{pv}(z_1) \text{ and } L\dot{z}_2 = uz_1 - v_{CP} \tag{1}$$

where z_1 and z_2 correspond to the capacitor voltage and the inductor current, respectively, $u \in [-1,1]$ is the control (duty cycle), $v_{CP} = A_{CP}sin(\omega t)$ is the voltage at the connection point and $f_{pv}(z_1) = \Lambda - \Psi e^{(\alpha z_1)}$ is the current delivered by the PV array. The controller requires a reference generator which generates the current reference, $\xi_2(t) = A_I sin(\omega t - \theta)$, to be tracked by the PV inverter. The values of the amplitude and phase of the current reference are calculated applying the well-known expressions that relate both values with the active and the reactive power references, see figure 1. The block diagram depicted in the figure 1 also shows the passivity-based controller proposed in this work. The controller determines the control signal from the values of the current reference, $\xi_2(t)$, the current injected to the grid, z_2, the PV array current, $f_{pv}(z_1)$, and the voltage at the connection point, v_{CP}.

The passivity-based control ensures global asymptotic convergence of the tracking error to zero when the active and the reactive power of the single-phase PV inverter are set and the PV inverter shows robust current tracking with fast dynamics. The control can be particularized in the cases of strong and weak grid operation. In the last case, the knowledge of the grid impedance and the injected active power allows to calculate the value of the required reactive power in order to set the amplitude of the voltage at the connection point. Numerical simulations when the power references are changed and when the PV irradiance varies have been developed to validate the control performance.

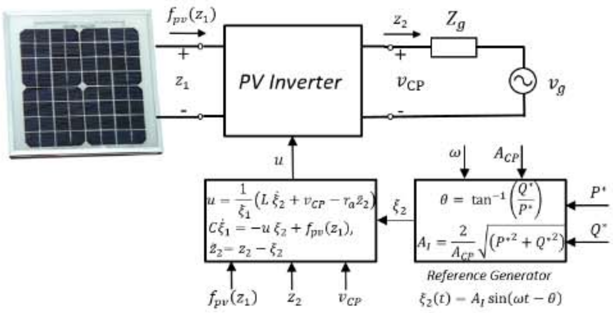

Figure 1: Passivity-based control of the active and the reactive power in PV inverters connected to the grid.

Acknowledgment

This work is partially supported by the Government of Spain through the Grant PRX16/00413, the Project DPI2013-41224-P and by the Generalitat de Catalunya through the Project 2014-SGR-267.

References

[1] C. Meza, D. Biel, D. Jeltsema, J.M.A. Scherpen. Lyapunov-Based Control Scheme for Single-Phase Grid-Connected PV Central Inverters, in IEEE Transactions on Control Systems Technology, March 2012.

[2] D. del Puerto-Flores, J.M.A. Scherpen, M. Liserre, M.M.J. de Vries, M.J. Kransse and V.G. Monopoli, "Passivity-Based Control by Series/Parallel Damping of Single-Phase PWM Voltage Source Converter," in IEEE Transactions on Control Systems Technology, July 2014.