Editorial

Special Issue “Advances in Control of Power Electronic Converters”

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Abstract: The use of power converters has grown in the last years with the advances in photovoltaic and wind based power generation systems, and the progress in modern concepts such as microgrids and electric mobility. A consequence has been the development of devices allowing for the exchange of energy among different distribution buses, and feeding AC or DC loads from low DC voltage levels, whose proper operation is achieved by means of specialized control systems. Simultaneously, the power converters used for conventional industrial applications have evolved thanks to the application of new control methods, and the combination of these with well-established techniques. This special issue contributes theoretical and practical advances to the state-of-the-art field at the crossroads of power electronics and control systems. The seven included papers cover particular applications requiring either DC–DC, DC–AC or AC–DC conversion stages.

Keywords: control of power converters; power electronics; control systems

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1. Introduction

Despite conventional techniques for the control of power converters established for several decades, the emergence of new challenges and the search for improved performance to ensure better energy utilization continues to motivate continuous and growing research in this area. The published results over the last years, both theoretical and practical, show the important impact of control design techniques which, associated with the significant recent progresses seen in the domain of materials, electronic devices or components, offer new perspectives in a domain where the problems become more and more complex. The objective of this special issue is to stimulate research in the area of control of power electronic converters, and promote the emergence of methods justified by rigorous theoretical analysis and validated with the help of simulation tools and experimental development. Among the eleven submitted papers to this special issue, only seven papers have been retained. Among them, three papers are focused on the control of DC–DC converters, three on the control of DC–AC converters and one on the control of a three phase rectifier.

2. Control of DC-DC Converters

The paper of Torres-Pinzon et al. [1] uses Takagi–Sugeno (T–S) fuzzy controllers to improve disturbance rejection and to optimize the control effort, guaranteeing the large-signal stability of power converters in a broad operation domain. The paper develops T–S models of boost and buck-boost converters, which were selected because of their non-minimum phase type dynamic behavior. Design of the fuzzy controllers is performed by using the Parallel Distributed Compensation technique (PDC). The approach is validated by means of simulation results for both converters, and experimental results are presented for the boost converter using a laboratory prototype of 60 W. For this work, it is worth highlighting that proposed control is entirely implemented using analogue electronics, i.e., passive components, operational amplifiers and multipliers.

Nedia Aouani and Carlos Olalla propose in [2] a novel framework for application of robust linear quadratic regulator (LQR)-based control in DC–DC power converters. In the same vein of the previous work, the controller design is performed using Linear Matrix Inequalities (LMIs) and Lyapunov stability theory, leading to a control ensuring robust stability. In this context, the converter is described by a linear parameter-varying polytopic model, integrating both uncertainties and rate of change of the stated variables. The successful operation of this method has been validated by means of simulated results using a conventional boost converter, providing comparison with a controller obtained using the method previously published in [3]. The main contributions of the work are the possibility to enlarge the region of uncertain parameters in which stability is ensured, and the improved regulation performance and robustness.

The paper by Gonzalez-Castaño et al. analyzes the undesired impacts of quantization (limit cycle oscillation) in the coupled inductor buck-boost converter when a two-loop digital current control is used to ensure output voltage regulation [4]. The selected control architecture involves an inner loop of multi-sampled average current control and an outer loop of voltage regulation. This work integrates design constraints for control gains and signal quantization to avoid these effects when the outer voltage loop is added. A laboratory prototype of 400 V and 1.6 kW is used to illustrate the presence of the studied phenomenon and verify the correctness of the proposed design conditions when the control system is implemented into a DSP. The contribution of this paper is highly useful to dealing with practical issues of both design and implementation of digital controllers for DC–DC power converters.

3. Control of DC–AC Converters

The paper by El Aroudi et al. [5] studies the steady-behavior of a differential boost inverter used for generating a sinewave AC voltage from a DC source. The dynamics of the converter are analyzed using an accurate discrete time approach, adopting a quasi-static approximation and the Floquet theory. The undesired sub-harmonic oscillation exhibited by the inverter in some intervals is accurately predicted by means of the complement between analytical expressions and computational procedures. The study provides stability boundaries in terms of the proportional gain of the PI controller used to track the output voltage reference. The results contribute to the design of a boost inverter avoiding the consequences of the sub-harmonic oscillation in the quality of the input current and the output voltage. The proposed simulation results validate the theoretical predictions and the accuracy of the analysis.

This contribution to the special issue [6] is focused on the same boost inverter as before. The objective is to reduce the voltage stress in power semiconductors by enforcing voltage references in the capacitor of the converters with a predefined harmonic content, which helps to decrease the voltage level required in each leg of the inverter for the entire cycle of the output voltage. Signal analysis allows definition that the voltage references with two harmonics is enough to achieve a considerable reduction of the voltage on the power semiconductors. To guarantee a proper tracking of the desired reference, two separate multiloop controllers were implemented, both using inner current control and outer voltage control. A complete linear modelling of the converter using the proposed control approach was derived from application of the equivalent control method. Moreover, qualitative analysis of the converter variables employing the harmonic balance method allowed them to derive a simplified plant model to facilitate voltage control design. The paper also compares the use of the proposed controller with the one developed in [7], showing how a small increase in complexity allows enforcement that minimum value of the capacitor voltages is close to the input voltage, then further reducing the voltage on semiconductors. A complete set of simulation results are provided for two electric standards (220 V/50 Hz and 120 V/60 Hz).

Iqbal et al. propose in their paper [8] a novel dead time compensation method for improving power quality and efficiency of inverters feeding induction motors. The

method is developed considering a three phase IGBT bridge feeding the load through an output inductor. An idealized nonlinear model of the inverter is used to obtain theoretical expressions defining the effect of the dead time on the variables of the inverter. The converter is controlled using a constant frequency Pulse Width Modulator (PWM). The validity of the approach is confirmed by means of simulation results using a common V/f strategy for speed variation of two case studies. The results show that the proposed method reduces Total Harmonic Distortion (THD), increasing the quality of the output current.

4. Control of AC–DC Converters

The paper presented in the field of AC–DC converters by Ortiz-Castrillon et al. puts forward a single surface sliding mode control, with an adaptive hysteresis band developed for the semi-bridgeless boost type rectifier [9]. The proposed control uses a single sliding surface which considerably differs to the classic cascade control architecture (a PI controller regulating the output voltage in the outer loop and a current controller to track appropriate references in the inner loop). The proposal integrates into the sliding surface a normalized term for the output voltage, one term for the current error and one term for its integral. All the conditions required to ensure stability of the sliding motion are validated, supporting the proposal theoretically, including start-up and large perturbation conditions. The paper provides both simulation and experimental results, validating the correct operation of the controller regarding tracking of the current reference, voltage regulation and disturbance rejection.

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