

# A DSP- and FPGA-Based Industrial Control With High-Speed Communication Interfaces for Grid Converters Applied to Distributed Power Generation Systems

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**Abstract**—New energy concepts such as distributed power generation systems (DPGSs) are changing the face of electric distribution and transmission. Power electronics researchers try to apply new electronic controller solutions with the capacity of implementing new and more complex control algorithms combined with internal high-speed communication interfaces. Thus, it is possible to monitor, store, and transfer a large number of internal variables that can be sent online to local or remote hosts in order to take new set points of different generation units. With this objective, this paper presents the design, implementation, and test of an industrial multiprocessor controller based on a floating-point digital signal processor (DSP) and a field-programmable gate array, which operate cooperatively. The communication architecture, which has been added to the proposed electronic solution, consists of a universal serial bus (USB), implemented with a minimum use of the DSP core, and a controller area network (CAN) bus that permits distributed control. Although the proposed system can be readily applied to any DPGS, in this paper, it is focused on a 150-kVA back-to-back three-level neutral-point-clamped voltage source converter for wind turbine applications.

**Index Terms**—Digital signal processors (DSPs), field-programmable gate arrays (FPGAs), power distribution control, power system communication.

## I. INTRODUCTION

CURRENT distributed power generation systems (DPGSs) have to execute complex control algorithms based on power unit internal and grid variables, which must be measured in real time, to generate the optimal references established in local or remote mode. Under these circumstances, it is necessary to develop electronic controllers with high computational power in addition to both internal and external high-speed communication capabilities.

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Nowadays, the control electronics of power converters, both in industrial and researching applications, are built from the following: 1) on-chip solutions based on fixed-point digital signal processors (DSPs) [1], [2]; 2) on-chip solutions based on field-programmable gate arrays (FPGAs) [3], [4]; and 3) systems which include a floating-point DSP, where the more complex control algorithms are executed, and an FPGA, whose simpler control algorithms and the periphery necessary to plug into the converters are implemented [5], [6].

On-chip solutions include, in a unique chip, the control algorithms and the interface modules with the power converter, such as pulse width modulation (PWM) generators, encoder readings, activation of contactors, etc. Therefore, the controller electronic is cheaper, more robust, and compact; the fault rate in the assembling process is considerably reduced; and the data transfers between processors are eliminated. To improve the operation, both fixed-point DSPs and FPGAs must be programmed in fixed point, which is a disadvantage with respect to floating-point DSPs. However, FPGAs provide higher performances in repetitive and massive computations than fixed-point DSPs, obtaining reduced execution times. In the last few years, the trend to use concurrent hardware for control purposes is increasing, and FPGAs are becoming more popular since they provide higher performances in repetitive and massive computations [7].

Comparing the DSPs, although the cost is similar, there still exist some technological differences between fixed- and floating-point DSPs. More mathematical flexibility, the accuracy, the smaller execution time, and the reduced development time make the floating-point DSPs an attractive solution for applications with data sets requiring real arithmetic. The main drawback of a floating-point DSP is its reduced amount of integrated periphery; therefore, an FPGA can be the device selected to implement these periphery modules. Otherwise, comparing floating-point DSPs with the FPGAs, the main advantages of floating-point DSPs are their software flexibility and capability to execute complex algorithms with many arithmetic operations. In spite of this, because of using a sophisticated programming, complex algorithms running in floating-point DSPs can be often executed in FPGAs with shorter execution times.

In this paper, authors present a control electronic system based on the third topology, that is to say, an integrated

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conquista a tus enemigos uno a uno o vé a la guerra total mar adentro

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insidioso pretendiendo ser caballeros magos piratas o ladrones el tiempo ha pasado pero los sueños de la infancia no han desaparecido y son los juegos en línea los que nos permiten hacer realidad nuestros sueños

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