Guest Editorial
Editorial Special Issue on Power Electronics for Microgrids—Part I

I. Introduction

WORLDWIDE electrical grids are expected to become smarter in the near future. In this sense, intelligent microgrids, which are able to operate in island or connected to the grid, will be a key point to cope with new functionalities, making the grid more stable, flexible, and efficient, thus allowing at the same time the integration of renewable energy resources [1].

A microgrid can be defined as a part of the grid with elements of prime energy movers, power electronics converters, distributed energy storage systems, and local loads that can operate autonomously but also interact with the main grid. The functionalities expected for these small local grids are black start operation, frequency and voltage stability, active and reactive power flow control, active power filter capabilities, and storage energy management, among others. This way, the energy can be generated and stored near the consumption points, increasing the reliability and reducing the losses produced by the large power lines. The proliferation of interconnected microgrids in one area can lead to the transformation of the distributed lines to tie lines for interchange relatively small amounts of power in order to achieve energy balancing.

In order to make this dream possible, there are a lot of efforts and interdisciplinary projects running in the whole world that conjugate different kinds of technologies such as power electronics, power systems, energy storage, telecommunication systems, and information technology, among others.

This special section deals with the study of several microgrid components that can contribute to make these small grids a new energetic paradigm. Researchers have been writing articles that cover a wide spectrum of the microgrids, especially here power electronics to develop interfaces between generation, storage, or dispersed loads.

The 25 high-quality papers approved for publication in this first part of the special section are organized according to the following six topics:

1) novel technologies for microgrids;
2) operation and protection of microgrids and distributed generation (DG) units;
3) control of parallel-connected inverters;
4) energy storage systems for microgrids;
5) low voltage direct current (LVDC) microgrids and high voltage direct current (HVDC) systems;
6) grid interactive applications.

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These topics and the papers included are explained in the following sections of this Guest Editorial. The second part of this Special Issue will appear in March of 2011.

II. Novel Technologies for Microgrids

The advances in novel technologies such as silicon–carbonate power electronics devices and supercapacitors based on carbon nanotubes are important elements to enhance efficiency and flexibility of the microgrids [2]. In this section, two papers deal with those new technologies.

1) "SiC power devices for microgrids," by Q. Zhang, R. Callanan, M. K. Das, S. Ryu, A. K. Agarwal, and J. W. Palmour, presents a review of the current status and future trends in SiC power electronics devices with respect to materials growth, device design, and fabrication processing.
2) "Energy storage and management system with carbon nanotube supercapacitor and multi-directional power delivery capability for autonomous wireless sensor nodes," by H. Chen, B. Wei, and D. Ma, proposes an energy storage and management system to achieve long lifetime and miniaturization for autonomous wireless sensor nodes, which can be used in communication network for microgrids.

III. Operation and Protection of Microgrids and DG units

Flexible operations of microgrids, i.e., seamless transfer from grid connected to islanding modes and protection, are key feature elements [3]. In this section, five papers about operation of microgrids, grid fault control, anti-islanding, and power calculations suitable for grid faults are presented.

1) "Protection principles for future microgrids," by H. Laaksonen, presents protection issues of low voltage microgrids and how high-speed, standard based (IEC 61850) communication can achieve fast, selective and reliable operation protection.
2) "Development of hardware in-the-loop simulation system for testing operation and control functions of microgrid," by J.-H. Jeon *et al.* The details of hardware-in-the-loop simulation of the operation modes of a microgrid are presented.
3) "Grid fault control scheme for three-phase photovoltaic inverters with adjustable power quality characteristics," by M. Castilla, J. Miret, J. Sosa, J. Matas, and L. García

de Vicuña, explores the performance of photovoltaic DG inverters under unbalanced voltage sags.

4) "Positive-feedback-based active anti-islanding schemes for inverter-based distributed generators: Basic principle, design guideline and performance analysis," by P. Du, Z. Ye, E. E. Aponte, J. K. Nelson, and L. Fan, shows the basic principles and design guidelines of positive-feedback-based anti-islanding schemes for multiple inverter-based DGs.
5) "Table-based direct power control: A critical review for microgrid applications," by J. Alonso-Martínez. A new formulation of direct power control is presented, regarding the power limits in which table-based algorithms are valid. This is important for microgrid applications, since they require a wide range of possible active and reactive power set points to control the system's voltage and frequency.

IV. Control of Parallel-Connected Inverters

The control of parallel-connected inverters has been studied for decades. Now, with the interest on microgrids, this topic is coming back [4]. This section consists of seven papers, and the major part of them is based on the droop control method.

1) "Control of parallel connected power converters for low voltage microgrid. Part I: A hybrid control architecture," by X. Yu, A. Khambadkone, H. Wang, S. Siew, proposes a hybrid control architecture to balance the power shared among the multiple interfacing inverters and optimize the system operating efficiency.
2) "Control of parallel connected power converters for low voltage microgrid. Part II: Dynamic electro-thermal modeling," by H. Wang, A. Khambadkone, and X. Yu, proposes a dynamic electro-thermal model that can be simulated with the power electronic circuit simulator, including a temperature-dependent loss and calculation of power semiconductor devices.
3) "A control strategy for a distributed power generation microgrid application with voltage and current controlled source converter," by E. Serban and H. Serban, presents a pseudodroop control structure integrated within a microgrid system through distributed power generation modules capable to function in off-grid islanded, genset- and grid-connected modes of operation.
4) "Virtual impedance loop for droop-controlled single-phase parallel inverters using a second order general integrator scheme," by J. Matas, J. Matas, M. Castilla, L. G. de Vicuña, J. Miret, and J. C. Vasquez, explores the impact of the output impedance on the active and reactive power flow between parallelized inverters operating with the droop method.
5) "Three degree of freedom robust voltage controller for instantaneous current sharing among voltage source inverters in parallel," by S. Shah and P. S. Sensarma, presents a three degree of freedom control scheme for parallel operation of three-phase inverters to enable equal load sharing even during transients while tracking a common sinusoidal voltage reference.
6) "Decentralized parallel operation of inverters sharing unbalanced and nonlinear loads," by D. De, and V. Ramanarayanan, proposes a droop control strategy with a virtual output impedance for parallel operation of three-phase four-wire inverters. The proposed system is suitable for nonlinear and unbalanced loads.
7) "Synchronization analysis of space vector PWM converters with distributed control," by M. Ma, X. He, and B. Williams, explores the control of distributed SVPWM strategy for DG inverters that generate their target output voltage vectors separately, while keeping simultaneously working with the command of the synchronization signal sent by the master inverter.

V. Energy Storage Systems for Microgrids

Distributed energy storage systems and their control and management are important when the microgrid works in island mode [5], [6]. Three practical papers are included in this section.

1) "Cooperative control strategy of energy storage system and microsources for stabilizing the microgrid during islanded operation," by J. Y. Kim *et al.*, proposes a hierarchical control strategy of a microgrid with an energy storage system for islanded operation. The energy storage system handles the frequency and the voltage as a primary control, and the energy management system works as a secondary control, controlling the power flown.
2) "The balance of renewable sources and user demands in grids: Power electronics for modular battery energy storage systems," by M. Bragard, N. Soltau, S. Thomas, and R. K. De Doncker, presents two battery storage systems including the power electronics parts: a 5-kW PV system for home applications and a 100-MW medium-voltage system for wind farms are presented.
3) "Single stage single phase high step-up ZVT boost converter for fuel cell microgrid system," by W. Li, W. Li, Y. Deng, and X. He, proposes a voltage multiplier cell inserted in the conventional boost converter operated in continuous conduction mode to provide another design freedom for the voltage gain extension. The approach is suitable for hybrid electric vehicles and fuel cell power conversion systems.

VI. LVDC Microgrids and HVDC Systems

Although major parts of the microgrids are conceived to run with alternate currents, there is a tendency or return back to direct current grids [7]. This section presents five papers based on both LVDC microgrids and HVDC systems for wind farms.

1) "Low voltage bipolar type dc microgrid for super high quality distribution," by H. Kakigano, Y. Miura, and T. Ise, proposes a high-quality power with three-wire dc distribution line for a residential complex. In this system,

each house has a local cogeneration system including gas engines and fuel cells.

2) "Predictive current controlled 5 kW single-phase bi-directional inverter with wide inductance variation for dc-microgrid applications," by T.-F. Wu, K.-H. Sun, L.-C. Kuo, and C.-H. Chang, presents the design and implementation of a 5-kW single-phase bidirectional inverter with wide inductance variation. For dc-microgrid applications, the bidirectional inverter can be used for grid connection and rectification with power factor correction to regulate the dc bus to a certain range of voltages.
3) "Novel digital-controlled transition current mode control and duty compensation techniques for interleaved power factor corrector," by K.-M. Ho, C.-A. Yeh, and Y.-S. Lai, proposes a digital-controlled transition current mode control technique for interleaved power factor correctors. A master–slave control technique is proposed to reduce the slave inductor current distortion and thereby achieving current sharing control between phases.
4) "Distributed voltage and frequency control of off-shore wind farms connected with a diode based HVDC link," by R. Blasco-Gimenez, S. Añó-Villalba, J. Rodriguez, F. Morant, and S. Bernal, presents a technique for the distributed voltage and frequency control of the local ac-grid in off-shore wind farms based on synchronous generators. The proposed approach allows the connection of the off-shore wind farm using a diode-based HVDC rectifier. The use of microgrid control techniques allows the system to be operated in current or voltage control mode.
5) "Control of HVDC light system using conventional and direct current vector control approaches," by S. Li, T. Haskew, and L. Xu, proposes an optimal control strategy for HVDC light systems using a dc vector control. The proposed approach is able to regulate active power, reactive power, and grid voltage support control.

VII. Grid Interactive Applications

Finally, the interactivity with the grid not only is mandatory in DG systems, but also represents a good feature for microgrids. This section includes three papers about grid-connected DG units.

1) "Full feed-forward of grid voltage for grid-connected inverter with LCL filter to suppress current distortion due to grid voltage harmonics," by X. Wang, X. Ruan, S. Liu, and C. K. Tse, proposes a feed-forward control for grid-connected inverter with LCL filter. The proposed control can reduce both the current distortion due to the grid voltage harmonics and the steady-state error of the injected currents.
2) "Efficiency improvement of grid-tied inverters at low input power using pulse skipping control strategy," by H. Haibing, W. Al-Hoor, N. Kutkut, and I. Batarseh, presents a pulse skipping control strategy to improve efficiency of grid-connected inverters at light loads. To maximize the efficiency, three key parameters are identified and optimized based on a loss modeling.
3) "A novel PV micro-inverter with coupled inductors and double boost topology," by Y. Fang and X. Ma, proposes a coupled inductor-double boost-inverter for photovoltaic grid-connected micro-inverter applications. The topology and the control endow good performances to the system.

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