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Editorial

Industrial Applications of Power Electronics

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Abstract: Electronic applications use a wide variety of materials, knowledge, and devices, which pave the road to creative design, development, and the creation of countless electronic circuits with the purpose of incorporating them in electronic products. Therefore, power electronics have been fully introduced in industry, in applications such as power supplies, converters, inverters, battery chargers, temperature control, variable speed motors, by studying the effects and the adaptation of electronic power systems to industrial processes. Recently, the role of power electronics has been gaining special significance regarding energy conservation and environmental control. The reality is that the demand for electrical energy grows in a directly proportional manner with the improvement in quality of life. Consequently, the design, development, and optimization of power electronics and controller devices are essential to face forthcoming challenges. In this Special Issue, 19 selected and peer-reviewed papers discussing a wide range of topics contribute to addressing a wide variety of themes, such as motor drives, AC-DC and DC-DC converters, electromagnetic compatibility and multilevel converters.

Keywords: power converters; electrical machines; power grid stability analysis; inverters; power supplies; power quality; multilevel converters; motor drives; power semiconductor devices; electromagnetic compatibility

1. Introduction

In recent years, power electronics have been intensely contributing to the development and evolution of new structures for the processing of energy. It is becoming very common to generate electrical energy in different ways and convert it into another form in order to be able to use it—for instance, renewable sources, battery banks, and the transmission of electric power in direct current (DC), which makes the voltage of the network available in different levels, in detriment to the supplied voltage from the grid [1]. The main users of these signals are pieces of electronic equipment that use voltages at levels different from that which is available from the grid; the drives of electrical machines, which modify the voltage of the electrical network (amplitude and frequency) to control the machines and finally, in electrical systems, DC power transmission and frequency conversion [2].

Two leading trends are currently noticeable in the power systems field of study. The first trend is the increasingly and prevalent employment of renewable energy resources. The second trend is decentralized energy generation. This scenario raises many challenges. Therefore, the design, development, and optimization of power electronics and controller devices are required in order to face such challenges. New microprocessor control units (MCUs) could be utilized for power production control and for remote control operation, while power electronic converters are and could be utilized to control the power flow [3].

Nevertheless, power electronics can be used for a wide range of applications, from power systems and electrical machines to electric vehicles and robot arm drives [4]. In conjunction with the evolution of microprocessors and advanced control theories, power electronics are playing an increasingly essential role in our society [5].

Thus, in order cope with the obstacles lying ahead, original studies and modelling methods can be developed and proposed that could overcome the physical and technical boundary conditions and at the same time, consider technical, economic, and environmental aspects. The objective of this Special Issue was to present studies in the field of electrical energy conditioning and control using circuits and electronic devices, with an emphasis on power applications and industrial control. Therefore, researchers contributed their manuscripts to this Special Issue, and contribute models, proposals, reviews, and studies. In this Special Issue, 19 selected and peer-reviewed papers contribute to a wide range of topics, by addressing a wide variety of themes, such as motor drives, AC-DC and DC-DC Converters, multilevel converters and electromagnetic compatibility, among others.

A significant portion of the currently produced electricity worldwide is mostly generated by centralized systems, based on conventional fossil fuel plants or nuclear power [6,7]. The barriers that policy makers, researchers, and engineers have to overcome when it comes to the operation and control of conventional power plants, and the development of low voltage power generation systems, have paved the way for diverse opportunities of energy generation, closer to the load, by the customers themselves, also known as distributed generation (DG) [8]. Thus, concerning this topic, several papers are published in this Issue.

In [9], an efficient H7 single-phase photovoltaic grid-connected inverter for common mode current conceptualization and mitigation is proposed. Specifically, an extended H6 transformerless inverter that operates with an additional power switch (H7) is utilised for improving the common mode leakage current mitigation in a single-phase utility grid. A new control for a modular multilevel converter (MMC) based static synchronous compensator (STATCOM) is proposed in [10] as an effective interface between energy sources and the power grid. This study showed that the proposed control method led to an effective reduction in capacitor voltage fluctuation and losses. The protection of sensitive loads against voltage drop is a challenge for the power system, especially in face of the rising use of DG. Thus, in order to address this obstacle, a compound current limiter and circuit breaker is proposed in [11] and validated through experimental and simulation results. The authors argue that in this study that the proposed compound current limiter is able to limit the fault current and fast break in order to adjust voltage sags at the protected buses. A data-driven based voltage control strategy for DC-DC converters, which are increasingly used to integrate renewable energy resources, with the aim of applying them to DC microgrids is given in [12]. Because these converters can be used for so many applications, suitable modelling and control methods are necessary for their voltage regulation. Simulations performed in this study show a satisfying performance of the data-driven control strategy. Since DG will most likely cause a higher occurrence of fault current levels, in [13], a multi-inductor H bridge fault current limiter is proposed in order to reduce the frequency of occurrence of such types of problems. Positive results are obtained through experimental and simulated tests.

As for research studies revolving around converters, a full-bridge converter (FBC) for bidirectional power transfer is presented in [14]. The proposed FBC is an isolated DC-DC bidirectional converter, linked to a double voltage source—a voltage bus on one side, and a stack of super-capacitors (SOSC) on the other side and real prototype, compliant with automotive applications. In [15], a single DC source multilevel inverter with changeable gains and levels for low-power loads is proposed. The validation of this inverter was conducted through simulation and experimental tests using nine different modulations. A p-type module with virtual DC links to increase levels in multilevel inverters is proposed in [16], which are able to produce higher voltage levels with a lower number of components, making them appropriate for a wide range of applications. In another study [17], Janina Rząsa proposes an alternative carrier-based implementation of space vector modulation to eliminate common mode voltage in a multilevel matrix converter and evidences that part of the high-frequency output voltage distortion component is eliminated. The proposed modulation method is validated though simulation and experimental results. A comprehensive comparative analysis of impedance-source based DC-DC and DC-AC converters regarding passive component count and size, range of input voltage variation, and semiconductor stress is proposed in [18]. The authors analyzed the main impedance-source converters with or without inductor coupling and with or without a transformer; useing simulations and experiments to validate this.

Converters and inverters are used for several applications, as gathered from the above-mentioned studies, and as so, they are also used for permanent-magnet synchronous machines (PMSM). An improved model predictive torque control combined with discrete space vector modulation for a two-level inverter fed interior PMSM is proposed in [19] and the authors establish a cost function involving the excitation torque and reluctance torque. Simulation and experimental results are used to validate this study, in which the torque ripple and current ripple is reduced. The nonlinear effects, such as voltage and command voltage deviation, of a three-level neutral-point clamped inverter on speed sensorless control of an induction motor are studied in [20]. In this study a new voltage deviation compensation measure based on the volt-second balance principle is proposed and validated through experimental results.

Extensive research is also made in the area of motor drives. A new effective use and operation of fuzzy-logic controller-based two-quadrant operation of a permanent magnet brushless DC motor drive system for multipass hot-steel rolling processes is proposed in [21], with validation through simulation and experimental tests provided. Another study [22], proposed a field weakening control method that employs interpolation error compensation of the look-up table based PMSM method. As in the majority of these studies, the improvement reached by using the proposed method is validated through experimental and simulation tests.

Non-linear ceramic resistors such as metal oxide ZnO-based varistors are mainly utilised to protect electronic and electric circuits from overvoltage. The ZnO varistor, also known as metal oxide varistor, is the most well-known type of varistor, and, as such, it is a topic that attracts attention from the research community. This Special Issue is no exception. An experimental study on the effect of multiple lightning waveform parameters on the aging characteristics of ZnO varistors is proposed in [23], in which the aging rate and surface temperature rise of ZnO varistor under the impact of multi-pulse current was examined. Another experimental study was made in [24] by focusing on the failure mode of ZnO varistors under multiple lightning strokes, in which alterations were observed in the performance of these ZnO varistors after multiple lightning impulses. These changes were analyzed from micro and macro perspectives.

In the semiconductor area of research, a robust electrostatic discharge reliability design of an ultra-high voltage 300-V power n-channel lateral diffused MOSFETs, with elliptical cylinder super-junctions in the drain side, is given in [25]. The authors have concluded that this is a decent strategy and the human-body model capability of these ultra-high voltage n-channel lateral diffused MOSFETs could be successfully improved without altering the basic electrical properties or adding any extra cell area.

In this area of electromagnetism, a novel AC magnetic transmitter current source circuit is proposed in [26] for the application of frequency domain electromagnetic method prospecting. The proposed current source circuit is able to generate high frequency and high constant amplitude currents, which are the main technical problems for the frequency domain electromagnetic method. The results obtained through simulation and experimental tests show that the proposed circuit achieves the linearity of the rising/falling edge, a short reversal time, a low power loss, and a constant amplitude. Since the penetration of electric vehicles is constantly growing in the market, in another study [27], a new topology-based approach to improve vehicle-level electromagnetic radiation is proposed due to the fact that electric vehicles suffer from various electromagnetic interferences. The efficacy of this method was demonstrated through experimental tests that compared the predicted vehicle-radiated emissions at low frequency with the obtained experimental results.

Improved control methods, better energy efficiency and problem mitigation can be achieved at any level and in almost any system, as can be seen in the contributions to this Special Issue. Even though numerous challenges still remain, research and technology are vital tools for overcoming the challenges that arise in power electronics, specially by heading towards responsible and careful use of the environment. Power electronics plays a key role in the development of renewable energy systems and, therefore, in reducing greenhouse gases. Therefore, through small incremental steps, the objective is to strengthen the role of innovation, with the aim of facing the challenges that lay ahead [28] with efficient responses that, additionally, can ensure an economical, reliable and sustainable electrical supply, on which we have grown to become so dependent.

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