Guest Editorial

IT IS AN honor and certainly a great pleasure for me to present this "Special Section on Matrix Converters." I began my first studies related to these fascinating converters 20 years ago, and during these two decades, I have observed how the research work has evolved, mainly from theoretical considerations to practical issues, which are being discussed these days. The matrix converter is an array of controlled bidirectional semiconductor switches that connect the voltage source directly to the load without the use of large reactive elements to store energy, as is usual in other power converters. This converter has some very attractive characteristics:

1) output voltage with unrestricted frequency;
2) sinusoidal input and output currents;
3) operation with adjustable (unity) input power factor;
4) full regenerative operation.

These important features are the reason for the tremendous interest in this converter topology, which became more realistic with the use of power transistors approximately at the end of the 1970s. In 1980, Venturini and Alesina introduced the name "matrix converter" and inspired many researchers to study this topology. During the 1980s, several control and modulation methods were developed to control this converter, using the most advanced concepts, like space-vector modulation.

The commutation of controlled bidirectional switches is very critical and difficult to achieve and, in this application, overvoltages or overcurrents, which can destroy the power semiconductors, can easily occur. Interest was reduced in this topology at the end of the 1980s because of this major problem. Another important drawback of this converter was the high count of semiconductors used to implement the bidirectional switches.

During the 1990s, several intelligent commutation techniques were developed with the use of powerful processors, avoiding any danger to the semiconductors. In addition, in the last two years, we have observed the introduction of power modules in the market with the complete circuit of a matrix converter in a single power chip. The most important drawbacks have been recently overcome, and this is the reason for the new interest in this converter and the reason for this Special Section, which includes 15 papers authored by researchers from academia and industry. These papers address the recent research work in this field.

This Special Section begins with a tutorial paper by Wheeler, Rodríguez, Clare, Empringham, and Weinstein. This paper presents the historical development of this converter, the most important modulation methods, the modern commutation techniques, and practical issues related to the application of this converter.

Two papers are dedicated to the commutation of the bidirectional switches. One of them, presented by Wheeler, Clare, Empringham, Bland and Apap, describes a novel commutation strategy using gate-drive-level intelligence in the form of a field-programmable gate array. The other paper, authored by Mahlein, Igney, Weigold, Braun, and Simon presents several commutation strategies with and without explicit measurement of the voltage polarity.

Four papers discuss modulation and control methods. Blaabjerg, Casadei, Klumpner, and Matteini compare two current modulation strategies for matrix converters operating under unbalanced input voltage conditions, which is a very important issue in this topology. In another paper, Casadei, Serra, Tani, and Zarri present a new method to study the modulation of the converter using a vector representation of the switches states. This approach makes it possible to reach the highest voltage transfer ratio and to optimize the switching pattern. Mutschler and Marcks use the space-vector theory in a direct control method that generates almost sinusoidal input currents. In their paper, Teichmann and Oyama present an alternative concept to avoid the need of staggered switching in matrix converters. This method is based on the auxiliary resonant commutated pole principle and can reduce the number of active devices.

Four papers address the use of modern power modules with integrated bidirectional switches. Klumpner, Nielsen, Boldea, and Blaabjerg analyze several aspects that should be considered to integrate bidirectional switches into a power module, proposing the configuration of a power electronic building block. Chang, Sun, and Wang present a highly compact converter using novel high-power 3-in-1 integrated power modules rated at 1200 V and 150 A, reducing the parasitic inductances. In addition, they report a high output voltage of 460 V from a source of 480 V. In another paper, Klumpner, Nielsen, Boldea, and Blaabjerg discuss the integration of the matrix converter and the induction motor in a single unit. In this paper, they demonstrate experimentally that this solution can be very compact, and it performs well. Finally, Simon, Mahlein, Muenzer, and Bruckmann present what they call modern solutions for industrial matrix converter applications. In this interesting paper, they introduce the first matrix converter contained in a single power module using insulated gate bipolar transistor technology rated at 1200 V, 35 A. In addition to this, these authors discuss commutation strategies, modulation methods, and overvoltage protection methods.

The overvoltage protection of the matrix converter is a very important aspect, especially when it is necessary to reduce the losses and the size of the components. Mahlein, Bruckmann, and Braun present an interesting overvoltage protection strategy based on the use of supressor diodes and varistors.

Two papers analyze the ride-through capability of matrix converters, an important issue in the practical application of controlled drives. Wiechmann, Burgos, and Rodríguez present a ride-through strategy for matrix converter adjustable-speed drives in the presence of voltage sags, regulating the modulation index first and reducing the reference speed if necessary. In

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another interesting paper, Klumpner and Blaabjerg introduce a ride-through strategy in the presence of short power interruptions. The strategy considers the control of energy in the capacitor of a common clamp circuit.

The matrix converter now faces strong competition from the voltage-source inverter with a regenerative input rectifier. For this reason, Bernett, Ponnaluri, and Teichmann compare a matrix converter with a voltage dc-link inverter fed by an active front end, evaluating the number of semiconductors, losses, filters, and protection.

Most of these papers validate their theoretical considerations with valuable experimental results.

I hope that this Special Section will inspire and motivate researchers to study the practical aspects that need to be investigated to achieve this converter being accepted in the market. I would like to express my appreciation to the authors for the quality of their contributions. Special thanks to Prof. J. Holtz, past Editor-in-Chief of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, for his encouragement and to Prof. F. Harashima, the new Editor-in-Chief, for his encouragement and support which made this Special Section possible.

I also want to express my gratitude to Em. Prof. G. Pfaff of the University of Erlangen, Erlangen, Germany, for giving me support to study and build a matrix converter and use it successfully in the vector control of an induction motor without destroying any single transistor, 20 years ago. Certainly, I am still very proud of that work. Finally, I am deeply indebted to the 34 referees from 14 countries for their valuable contributions to the review process.

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