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EDITORIAL

SPECIAL SECTION

Multilevel Converters

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The area of power electronics and controlled drives is a major and important discipline in electrical engineering. Power electronics, which basically deals with high efficiency conversion and control of electrical energy, has found various applications, such as: DC and AC machine drives, active harmonic filtering, induction heating, AC and DC power supply, active and reactive power flow control, high-voltage direct-current (HVDC) energy systems and flexible AC transmission systems (FACTS), coupling of energy storages in distributed generation (DG) and smart grid (SG) systems, solid state transformers (SST), contactless energy transfer, etc. [1–3]. Therefore, appreciating the importance and fast development of power electronics, three special issues dedicated to this topic had been published in the *Bulletin of the Polish Academy of Sciences: Technical Sciences* until 2017:

- "Control in Power Electronics and Drives", *Bull. Pol. Ac.: Tech.* 54 (3), 2006.
- "Power Electronics in Renewable Energy Systems", *Bull. Pol. Ac.: Tech.* 57 (5), 2009.
- "Power Electronics for Smart Grids", *Bull. Pol. Ac.: Tech.* 59 (4), 2011.

The newest Special Section is intended to focus on recent research and trends in application of multilevel converters. Multilevel converters have been extensively developed over the last two decades and show several important advantages of power electronic circuits, such as: operation at high voltages, harmonics reduction, higher efficiency, modularity, smaller size and lower cost. Also, thanks to increasing interest in renewable energy systems (RES) and SGs, the development of multilevel converters is considerably accelerated. The papers included in the presented special section are grouped into the main categories that follow.

1. **Survey papers presenting the state of the art of cascaded multilevel converters [4] and converters for interfacing different types of energy storage [5].** The paper authored by an outstanding specialist from the Warsaw University of Technology, Poland, M. Malinowski [4] have a survey nature, covering different aspects of the technology and its applications. As shown, the cascaded multilevel converters can easily operate at medium and high voltage based on the series connection of power modules using standard low-voltage components. It allows for low THD output voltages and input currents, reduction of passive components and redundancy of components. Thanks to these features, the cascaded multilevel converters have been recognized as attractive solutions for HVDC transmission, SST and photovoltaic (PV) systems.
   The timely problem of how to interface different types of energy storages with power grid is addressed by an exceptionally experienced team of specialists: A. Domino, K. Zymmer and M. Parchomiuk from the Electrotechnical Institute (IEL), Warsaw, Poland [5]. They present an overview of converter topologies for energy storage, such as superconducting magnetic energy storage (SMES), supercapacitor energy storage (SES) and chemical batteries.

2. **Modern predictive control methods developed for 5-level converter [6], 4-leg 3-level active filter [7], and 3-level grid-connected converter [8].** In power electronics, the model predictive control allows to change the control structure from classical series connected regulators (cascade structure) to one controller operating with on-line optimization. This is now possible, in spite of a high number of calculations required, thanks to very fast DSPs and FPGA processors. Therefore, many researches attempt to develop new algorithms optimizing several converter parameters in on-line fashion. How the current control in 5-level converter with boost capability can be implemented based on predictive model is presented by researchers from the Electrotechnical Institute (IEL), Warsaw, Poland, P. Wiatr and A. Kryński in [6]. This work presenting experimental results is a continuation of paper [16], in which a simulation study was described. The problem of calculation reduction in complicated control algorithm of the 4-leg 3-level flying capacitor converter (FCC) operating as shunt active power filter (SAPF) is discussed in the work by K. Rafał and K. Antoniewicz from Warsaw University of Technology, Poland [7]. The control algorithms of an AC-DC grid-connected converter have to provide not only a sinusoidal shape of grid current, but also stable operation during transient states in the grid, e.g. voltage dips or voltage unbalance.

This problem has been deeply discussed by a team from Bialystok University of Technology P. Falkowski, K. Kulikowski, and R. Grodzki in [8], where three modern predictive control algorithms are presented and investigated under grid voltage distortions.

3. **Space vector modulation (SVM) in multilevel converters [9] and in special application [10].** The fundamental problem: how to compensate for DC-link voltage unbalance in a 7-level cascaded H-bridge converter is considered in paper [9] by A. Lewicki and M. Morawiec from Gdansk University of Technology, Poland. The proposed SVM method allows to maintain the same balanced voltage level on all converter capacitors and generate the output voltage vector properly also in the case where the DC-link voltages are not balanced. The effect of SVM algorithm on current vector ripples, analyzed using the mathematical model of 3-level three-phase voltage inverter with symmetric active inductive load, has been discussed by V. Tomasov, A. Usoltsev, P. Zolov and P. Gribanov from ITMO University, St. Petersburg, Russia [10]. Some limitations on application of such inverters for precision drive control in optical telescopes were specified.

4. **Special issue of high power multilevel converters [11–15].** The design and investigation results of switched capacitor voltage multipliers for application in high power systems is presented by the team of outstanding specialists from AGH University of Science and Technology, Krakow, Poland [11]. The considered family of multilevel converters includes classical topologies and also novel concepts. The application of thyristors as well as invention of novel concepts of multiplier topologies with appropriate control make it possible to achieve high efficiency, high voltage gain, as well as reliable and simple DC-DC converters for high power systems. The fundamental problem of how to increase the DC fault ride-through capability of a full-bridge modular multilevel converter (MMC) station while ensuring a stable controlled operation as a STATCOM during DC faults without the need for fault isolation is deeply discussed and well illustrated by the international team of excellent researchers E. Kontos, and P. Bauer from Delft University of Technology, The Nederlands with G. Tsolaridis and R. Teodorescu from Aalborg University, Denmark in [12]. Similarly, paper [13] presenting a comparative analysis between simulation results delivered for 2-level and 3-level 3kV traction drive system regarding generation of disturbing current harmonics, is written by an international team of authors: M. Steczek from Lodz University of Technology, Poland, A. Szeląg from Warsaw University of Technology, Poland, and D. Chatterjee from Jadavpur University, India. This problem is very important because every traction vehicle to be authorized for operation on railway lines must comply to the limits imposed on current harmonics magnitudes. In paper [14] by M. Morawiec and A. Lewicki from Gdansk University of Technology, Poland, the control strategy for power electronic transformer (PET, also known as SST) is proposed. The analyzed structure uses two 7-level cascaded H-bridge (CHB) rectifiers. The electrical power is transferred between DC-links of CHB converters using dual-active-bridges (DABs) and low voltage high frequency transformers. The system allows to control the active and reactive power with low level of harmonic distortions. Finally, the last paper in this group, written by P. Błaszczyk, K. Koska and P. Klimczak from ABB Corporate Research Center, Krakow, Poland, presents energy balancing in modular multilevel converters (MMC). The analysis includes multi-converter systems, and the MMC control system is divided into hierarchical levels. It is important that experimental results, based on multi-converter test setup, are also added.

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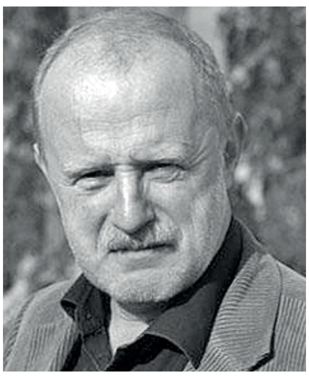

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