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EDITORIAL

SPECIAL SECTION

New control algorithms, modern devices, and materials in electric energy conversion systems

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1. INTRODUCTION

Innovative energy conversion systems play a key role in the sustainable development of contemporary and future technology and are used in most systems supporting everyday human activity. The paradigm of electricity generation is changing. From the central model, there is a shift to distributed generation, especially from renewable energy sources (RES). Efficient and precise drive systems that convert electric energy into motion are used in transport, robotics, medical technologies, electromobility, and numerous industries. All these factors create a constant need for research into new devices, materials, and technologies used in electric energy generation, storage, and conversion as well as drive systems. And, as it is well known, even the most perfect technologies in this field are useless without appropriate control (software) algorithms.

Therefore, the Bulletin of The Polish Academy of Sciences Technical Sciences, which continuously stimulates the development of research devoted to the most important challenges of modern technology, presents this Special Section. Topics related to power electronics and electric drive automation have been in the spotlight for many decades. The presented Special Section continues the long tradition of publishing papers related to this field in the BPASTS. Let us mention previous special sections: "Control in Power Electronics and Drives", Bull. Pol. Acad. Sci. Tech. Sci. vol. 54, no. 3, 2006, "Power Electronics in Renewable Energy Systems", Bull. Pol. Acad. Sci. Tech. Sci. vol. 57, no. 4, 2009, "Power Electronics for Smart Grids", Bull. Pol. Acad. Sci. Tech. Sci. vol. 59, no. 4, 2011, and the recent ones: "Multilevel Converters", Bull. Pol. Acad. Sci. Tech. Sci. vol. 65, no. 5, 2017 [1], and "Adaptive, predictive and neural approaches in drive automation and control of power converters," Bull. Pol. Acad. Sci. Tech. Sci. vol. 68, no. 5, 2020 [2].

Researchers remain exceptionally active in the area defined by the topic of this Special Section. Several important monographs published recently were created on the initiative of this research community [3–5]. This activity is regularly summarized at bi-annual conferences Control in Power Electronics and Electric Drives (Sterowanie w Energoelektronice i Napędzie Elektrycznym – SENE). Therefore, the guest editors of this Special Section addressed the call for papers to the participants of the 16th Conference on Control in Power Electronics and Electric Drives – "SENE 2023"; however, all researchers active in the field indicated by the Special Section theme were welcome to submit papers. From the many submitted contributions, ten papers covering important and current problems of electric energy conversion systems, drive automation, and power electronics, were selected.

The presented papers are naturally divided into two groups, which will be briefly described.

2. ELECTRIC DRIVES – CONTROL AND IDENTIFICATION

Nowadays, various electric drive systems are ubiquitous in modern technology and appliances of everyday life. European Commission estimates that there are about eight billion electric motors in use in the EU, consuming nearly 50% of the electricity the EU produces [6]. Therefore, efficient, and high-performance control of drives is crucial from the technological, economic, and environmental point of view. Papers on electric drives presented in the Special Section correspond to the main stages of the drive life cycle: modelling, design of control algorithms, and safe and energy-efficient operation and they were presented in this order.

Among the numerous designs of electric motors, reluctance motors deserve special attention because they do not contain rare earth metals, unlike permanent magnet machines. Unfortunately, a precise motor model is required to apply velocity control of a reluctance machine efficiently. The paper "Dynamic modeling and identification of a reluctance synchronous machine parameters" by Ł. Niewiara, M. Gierczyński, T. Tarczewski, and L. Grzesiak describes a novel technique for the identification of such a model.

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A novel, nonlinear robust control of motion is presented in the paper "Robust control of motion in presence of uncertain parameters and control constraints" by M. Jastrzębski, J. Kabziński, and P. Mosiołek. The desired behaviour of the position and velocity signals is obtained by imposing a time-varying constraint on the signal aggregating information about position and velocity tracking errors. The proposed method allows you to determine the maximum control (servo drive current) necessary to achieve the control goal under the existing initial conditions and the selected reference trajectory.

The safe operation of a modern drive system is even more important than the high performance of control. Therefore, fault identification and fault-tolerant control are rapidly developing techniques of electric drive automation. Two next papers from the presented Special Section concern this topic. The first one, "Current sensor fault-tolerant control based on modified Luenberger observers for safety-critical vector-controlled induction motor drives" by M. Adamczyk and T. Orłowska-Kowalska, focuses on current sensor fault-tolerant control in induction motor drive systems. The most popular field-oriented control is addressed. Two modified Luenberger observers are proposed as fault sensors, and current sensor faults that occurred both during motor and generator operation, as well as in dynamic states, were properly detected. In the next paper "Application of continuous wavelet transform and convolutional neural networks in fault diagnosis of PMSM stator windings" by P. Pietrzak and M. Wolkiewicz, a wavelet transform and convolutional neural networks are applied for fault diagnosis of PMSM stator windings.

As power converters and current regulators have become faster and more reliable, the mechanical parts of drives are becoming a major source of problems. The paper "Theoretical and experimental comparison of gear systems: planetary mechanical transmission and coaxial magnetic gear" by J. Kołodziej, R. Gabor, M. Kowo, and M. Łukaniszyn concerns the most complicated part of a motion transmission system – a gearbox. The paper provides a comparative analysis of selected mechanical and magnetic gears, using a specific example to point out the advantages and disadvantages of contactless power conversion. The effects of temperature and load on losses were measured and simulated, and ultimately, the efficiency characteristics of the two gears were also compared.

3. SMART POWER CONVERTERS AND MATERIALS FOR ELECTRIC DRIVES AND MODERN GRID-CONNECTED APPLICATIONS

In recent years, mainly due to the mass-scale introduction of renewable energy sources, electrical energy – its control, storage, and management – is based on power electronic converters. However, at the end of the 19th and beginning of the 20th century, "the current war" of AC and DC systems was a fact, and today they co-exist. Professor Jan Czochralski, who invented the crystal growth method, did not expect probably that, thanks to his invention, diodes, thyristors, and finally transistors would change the way of living on Earth [7, 8]. Our civilization obtained the possibility of utilizing electrical energy from the range of pW to TW in microcomputers, utility grids, automation, medicine, and any other hi-tech technology. Life without electricity, electronics, and informatics is almost impossible at the beginning of the 21st century.

Thanks to the dual active bridge (DAB) topology introduced in [9] the bidirectional power flow with galvanic isolation between different DC voltage levels is possible and almost as easy as a classical AC transformer. After over 30 years of research work [10], there are still issues to be solved as shown in the paper "Selected aspects of the operation of dual active bridge DC/DC converters" by S. Bachman, M. Turzyński, and M. Jasiński.

DC/DC conversions are widely used in personal computers (PC) for any kind of power supply especially the most important is the "phases" of power supply for central processing unit (CPU), double-data-rate x synchronous dynamic random-access memory (DDRx SDRAM) or the graphics processing unit (GPU). In most cases, the operation of the PC is possible so efficiently because step-down (buck) converters are used. It is no secret that remarkably similar buck converters are used in power supply units (PSU) of almost all hi-tech appliances.

For over 10 years wind-bandgap (WBG) semiconductors like silicon carbide (SiC) and gallium nitride (GaN) have been improving the parameters of the power converters. A good example is the converter discussed in "Resonant step-down DC-DC converter based on GaN power integrated circuits and SiC diodes", where the authors (R. Stala, S. Folmer, and A. Mondzik) combine these technologies within one converter to reduce power losses. In reference to the papers on electric drives mentioned earlier, P. Siwek and K. Urbański report very good performance of such a system with emerging topology based on the impedance network. According to "Quasi Z-source direct matrix converter for enhanced resilience to power grid faults in permanent magnet synchronous motor applications" the drive system can work during voltage sags (dips) on the grid side improving operating conditions of the permanent magnet synchronous motor. Hence, as a result, it could improve the resilience of the power system. Moreover, another paper in this session, "Experimental test results of an automatic voltage regulator with independent phase voltage controllers" is also focused on very common problems with voltage imbalance in the power grid. W. Śleszyński and others prove that automatic voltage regulation can be obtained with a smart power electronic system.

Overall, the mentioned papers show an outstanding scope of recent research work in the area of power electronic converters.

It is worth mentioning that PWM techniques and WBG transistors facilitate changing the frequency and duty cycle in an exceptionally wide range (from Hz to GHz). A good example of such applications is "Reconfigurable smart metamaterial for energy transfer control in alternating magnetic fields", by A. Steckiewicz and A. Stypułkowska. As a result of smooth control signal change "the complex effective magnetic permeability of the metamaterial can be smoothly changed." Such abilities can be utilized in wireless power transfer (WPT), among others. All parameters of the energy can be controlled by power electronics devices, like THD, P/Q ratio, and power factor.

Control methods are now becoming a kind of sophisticated software that is responsible for reliability, resilience, cybersecurity, energy transfer accuracy, and efficiency.

Information technology (IT) is a tool and a basis for a new dimension of life – a virtual part (software, digital tween, cloud computing, blockchain, etc.). Thanks to our imagination, we can implement ideas by IT and change the real world by PC, and smart power electronics converters (SPEC) which can be used in the new control algorithms, modern devices, and materials in electric energy conversion systems. These algorithms are becoming nowadays like software that should and must be protected by hacker-resistant shields. Real-time human-machine interaction systems are the most sophisticated applications (robotics, etc.) but this will be the subject of another special section.

4. CONCLUSIONS

The idea of this Special Section was born during the last, 16th Conference "Control in Power Electronics and Electric Drives" – "SENE 2023", organized every two years in Łódź, by the Institute of Automatic Control, Lodz University of Technology. Numerous researchers representing the majority of technical universities in Poland take part in each edition of this cyclical conference. It is undoubtedly the largest and most representative scientific conference in this thematic area in Poland. All participants create an exceptional, stimulating atmosphere by demonstrating a mutual interest in their results. As the effect of this stimulation, the leading topics of the Special Section were proposed by Guest Editors and kindly accepted by the Editorial Board. We hope that the selected papers represent a high scientific level and strong practical applicability, will interest, and inspire our readers, and motivate them to participate in the next conference.

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Jacek Kabziński – The chairman of the Scientific Committee and the main organizer of the cyclical conference Control in Power Electronics and Electric Drives http://sene.p.lodz.pl/, the oldest and the most representative scientific conference in this thematic area in Poland, initiated the idea of this Special Section. He holds a professorship at the Lodz University of Technology. For many years he has been the Head of the Control Theory Department at the Institute of Automatic Control, Lodz University of Technology. He specializes in nonlinear, adaptive, and robust control, applications of artificial intelligence in control systems, and applies his research to the control of electromechanical and robotic systems. He is the author of 190 scientific publications, editor of collective monographs at the Springer publishing house, author of academic manuals on control theory and numerical analysis. He served as the Director of the Institute of Automatic Control, also as the Chairman of the Polish branch of the Control Systems Society IEEE. He is a member of numerous scientific committees of conferences and journals in the field of control and artificial intelligence.

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