by Marian P. Kaźmierkowski, Szymon Piasecki, Frede Blaabjerg, Huang-Jen Chiu, and Marek Jasinski

Fruitful Cooperation Between Science and Industry Is Possible: We Prove It by Examples

We would like to focus on some good examples from the IEEE Industrial Electronics Society (IES) fields of fruitful academia–industry cooperation and the role of students and young professionals. The IES is multidisciplinary, and to describe all fields would be impossible in a single article. This time, we will look at energy conversion by discussing industrial and power electronics (PE).

Energy conversion is quite a hot topic and exists in most fields within IES's membership, differing only by rated power. Let's focus on three examples. There is a hope we will find a way in the future to disseminate outcomes from this academia–industry synergy by using groups like IEEE Women in Engineering, mentors with students and young professionals, as well as tutorials and seminars given online for free. This is a positive effect of the COVID-19 pandemic. A good example of such seminars is the series by the IEEE, Connecting Experts [1], and prepared by the IEEE Region 8 Young Professionals [2] in cooperation with all IEEE Societies, including the IES [3]–[5].

An interesting seminar was given by Prof. Dr. Sertac Bayhan, "Microgrids: The Pathway to Smart and Cleaner Energy Future." It was chaired by Dr. Naki Güler of Region 8, Turkey, who is the IES and Power Electronics Society (PELS) Young Professionals representative. Dr. Güler is the recipient of the IES and Students and Young Professionals Activity at the 2018 International Conference on Compatibility, Power Electronics, and Power Engineering, Doha, Qatar.

Dr. Bayhan provided the following summary of his webinar:

> Over the last few decades, electrical energy systems have become overstrained and faced various stressed conditions more often because of increased electricity demand and the adaptation of various fluctuating renewable energy resources. Undoubtedly, at some point within the next decade, intensive electricity demand will exceed total electricity generation and transmission capacity, which will force decision makers to build new plants and put major changes in the whole grid infrastructure. Such solutions will not be practical considering economic, safety, and environmental concerns. Therefore, the traditional utility grid has to experience an inclusive transformation to avoid a prospective crisis with existing power plants and available infrastructure. To ensure electricity continuity and minimize the difference between the supply and demand energy, the smart grid paradigm has to be introduced with solutions that include demand response, energy efficiency improvement, and renewable energy integration. To combine these three elements in an appropriate and reliable solution, microgrids play an important role to meet future electricity demands without significant investment in new power plants. This talk primarily focused on design consideration of microgrids, including the current status and also future opportunities of renewables, energy storages, PE, microgrid control techniques, and the challenges of integrating microgrids into the electricity grid."

As a result, we will see interesting material on the Internet after the event (Figure 1). Let us focus now on potential cooperation between academia and industry.

Aalborg University

Aalborg University (AAU) [6] offers education and research within the fields of natural sciences, social sciences, humanities, as well as technical and health sciences, and it is a dynamic and innovative research and educational institution oriented toward the surrounding world. AAU is characterized by combining keen engagement in local, regional, and national issues with an active commitment to international collaboration; and since its establishment in 1974, all university programs have been based on problem-based learning. AAU students work in groups applying problem-oriented methods when preparing projects at high academic standards. In 2014, 44% of all master's theses were prepared in cooperation with companies or other external partners.

At the moment, more than 23,000 students (full time and part time) are enrolled at AAU, ranging from students in preparatory courses to doctoral-level candidates. AAU employs approximately 3,300 professionals within the scientific and administrative fields. AAU ranks among the best

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and most acknowledged international universities in the world. According to *The Times Higher Education Supplement*, AAU is solidly placed in the top 100 in engineering and science.

The Department of Energy Technology [7] has a series of world-class laboratory facilities at its disposal where researchers and students do much of their work. Companies and organizations can gain access to these laboratories. The expansion and renovation of the department's laboratories offer students and cooperating partners access to some of the research world's most advanced and modern facilities in the energy sector.

PE is one of the strategic areas of study and research at the department, aiming to produce new knowledge and prepare national and international candidates. The department has a unique academic mix of staff members who are involved in intensive PE research on efficient and reliable energy production, control, consumption, and utilization. Efficient and reliable PE is the core focus of the PE program, to which two world-class research centers—the Center of Reliable Power Electronics (CORPE) [8] and IEPE (Intelligent Efficient Power Electronics) [9]—and one national—the Center of Excellence (X-POWER) [10]—are affiliated. All facilities are at the disposal of the project. The team engages in considerable collaboration with industry, for example, with Vestas Wind Systems, Danfoss, Grundfos, Energinet, Mitsubishi, Sanken Electric, Huawei, Schneider Electric, and Fuji Electric [11]–[19].

Established in 2011, CORPE is a strategic research center situated between the industry and universities, led by AAU. CORPE is addressing how the reliability of PE devices and systems is influenced by different stress factors such as temperature, overvoltage and current, overload, and environment. Furthermore, it is developing device and system models that enable simulation and design of PE systems very close to the limits of the components as well as models that enable designed reliability. The knowledge is also used online during testing to predict product lifetimes, to enable smart de-rating of the equipment still in operation, and to ensure extended lifetimes.

Over the years, CORPE has pursued both academic excellence and industry applicability, and it is the leading research center globally on PE reliability. Besides its worldwide research dissemination in top-tier journals, international conferences, books, courses, keynotes, tutorials, and invited industry seminars, one very important outcome is the development of well-educated master's and doctoral students as well as visiting scholars with multidisciplinary expertise in both PE and reliability engineering, who are in high demand in both Danish and international companies and universities.

Warsaw University of Technology and TWERD Power Electronics

TWERD Power Electronics Ltd. (Zakład Energoelektroniki TWERD Sp. z. o. o.) [20] is a Polish producer of PE devices (Figure 2). Founded in 1989, the company employs 35 people, of whom 15 are staff members whose main area of activity is R&D.

The company produces modern PE devices that enable processing,

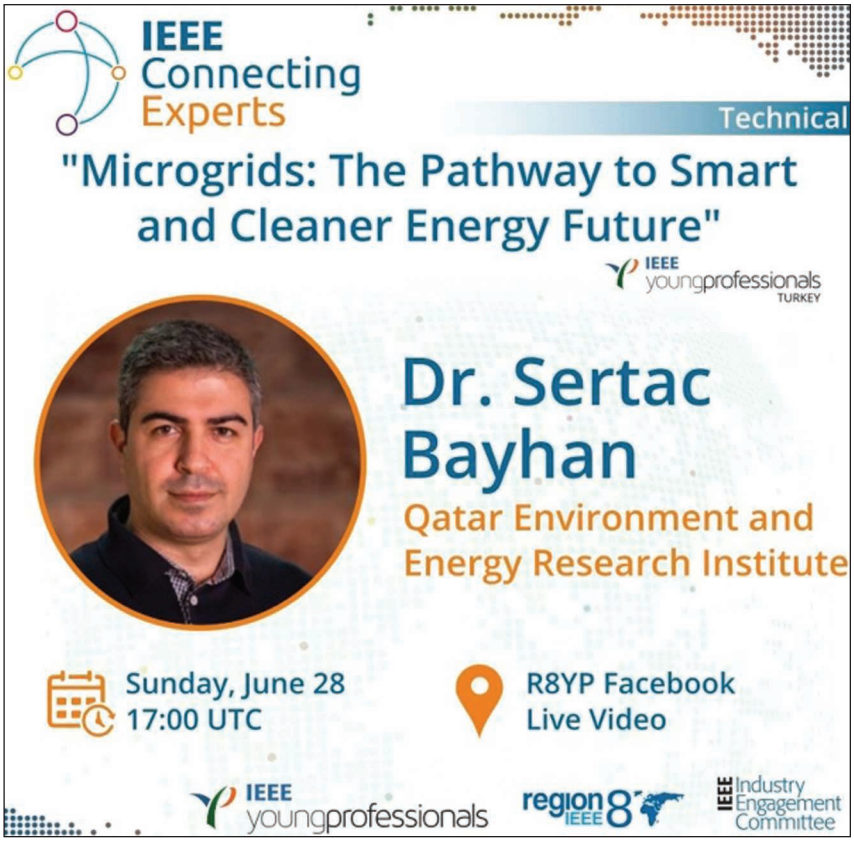


FIGURE 1 – The IEEE Connecting Experts webinar by Prof. Dr. Sertac Bayhan, which was chaired by Dr. Naki Güler.

FIGURE 2 – The TWERD Power Electronics headquarters, located in Torun, Poland [20]. (Source: TWERD Power Electronics; used with permission.)

storage, and the appropriate use of electrical energy (Figure 3). Its principal products include a wide range of drive inverters that can handle from several hundred watts up to 2.5 MW for applications in industry and heavy industry. The company has worked with the mining industry to create drives for roadheader mining machines and conveyors. Another area of activity is the production of converters for renewable energy sources [photovoltaic (PV), wind, and water energy] and converters dedicated to work with energy storage systems. These solutions include converters for energy storage with capacities up to 500 kWh, which are used in hydroelectric power plants or dedicated for energy systems and distribution system operators.

A new family of products focuses on electromobility, such as electric vehicle chargers (dc and ac) and drive inverters for applications in electric buses and cars. With high R&D potential, the company also consistently develops specialized solutions and projects dedicated to individual and unusual customer needs. TWERD's products outside of Poland are sold in Germany, France, the United Kingdom, the United States, Austria, Qatar, Russia, Israel, Ukraine, Belarus, Venezuela, the Philippines, Kazakhstan, and China.

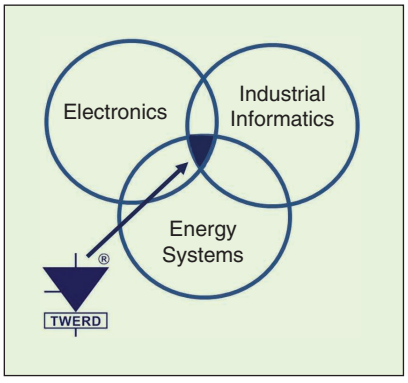
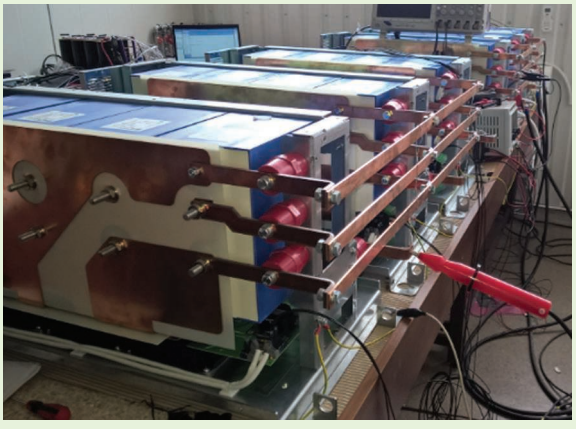


FIGURE 3 – The areas of research and production activity of TWERD Power Electronics. (Source: TWERD Power Electronics; used with permission.)

The development and wide range of TWERD's products are an example of fruitful cooperation between science and industry. The company has collaborated with such scientific units as Lviv Polytechnic, the Gdańsk University of Technology, the Electrotechnical Institute (Warsaw), and the Warsaw University of Technology. The relationship between Michał Twerd, TWERD's chief executive officer, and Prof. Marian P. Kaźmierkowski, developed in 1999, has evolved into a long-term cooperation on various projects, joint research, and developmental work. Collaboration with the international scientific community has resulted in the implementation of more than 20 R&D projects cofinanced by the European Union and national funds. The results of this R&D have led to the introduction of a number of new technical solutions and innovative products, which have received numerous awards and distinctions. The most interesting completed research projects include:

1) A sensorless inverter drive with direct torque control for 315-kW induction motors based on a new signal processor; a direct power control space vector modulated for a three-phase, pulsewidth modulation rectifier (55–300 kW); and a sensorless inverter drive for a permanent-magnet synchronous motor with direct torque control, which resulted in the development of a family of two-level inverters of the MFC710 series with vector control, a sensorless operation mode, and active front-end applications. TWERD was the first Polish producer of inverters to implement vector control, the sensorless operation mode, and methods based on direct power control (from the grid side) and direct torque control (from the machine side).
2) The elaboration and application of a three-level, neutral-point clamped bidirectional ac–dc–ac converter (150–800 kW), operating on a wide range variation of the grid voltage; and a series of three-level, bidirectional, medium-voltage ac–dc–ac 3.3-kV converters with 0.5- to 2-MVA power for applications in the mining industry, which resulted in the development of a family of three-level, MFC810 inverters, dedicated to mining applications for ac voltages up to 3.3 kV. These product lines were the basis for the development of cooperation between the company and the

(a)



(b)

FIGURE 4 – Some of TWERD Power Electronics' equipment and products: (a) a high-power engine room and (b) a 1-MW ac–dc–ac converter, with a voltage of 3.3. kV, designed for applications in the mining industry. (Source: TWERD Power Electronics; used with permission.)

mining industry, which is constantly growing (Figure 4).

3) The development and implementation of a comprehensive, bidirectional ac–dc–ac converter system (45–200 kW), which is used for high-pressure pumping stations with reverse-flow control. The project resulted in the development of a product dedicated to applications in the petroleum industry, and is used in Venezuela.
4) A series of single-phase (2.3 and 5.5 kW), high-efficiency and transformerless ac/dc converters for PV panels and a modular PE system for sustainable energy management from renewable sources with a storage function for household and industrial applications, which resulted in the development of a family of single- (PS100) and three-phase (PS300) grid converters dedicated to renewable energy sources. An additional converter module is being explored for energy storage systems and off-grid operations.

TWERD's collaboration with the Warsaw University of Technology and IEEE Members working there, including Prof. Kaźmierkowski, Prof. Mariusz Malinowski, Prof. Jacek Rabkowski, Dr. Sebastian Stynski, Dr. Marcin Żelechowski, and Prof. Marek Jasinski, is a great example of the synergy between academia and industry. Thanks to this close cooperation, ideas developed at the university have been successfully implemented in the form of innovative solutions and products. TWERD's business practices help students and young university graduates to participate in research while in direct contact with the industry, to learn about the pressure of working with real applications, and to deal with problems encountered in industry. Existing and developing cooperation is fruitful; it brings inspiration and ideas to both parties. The company is constantly developing its R&D potential, while members of the academic community receive inspiration and real-world problems that require the creation of solutions with a focus on industrial applications.

Close and friendly collaboration requires creating opportunities for meeting and developing a space to exchange thoughts, views, and ideas. IEEE initiatives and support have made a significant contribution to this end. The funds of the IES Chapter and the energy of its members have supported the organization of a series of seminars and meetings between scientific and industrial employees, both at the professional and the social level (Figure 5). Established cooperative ventures are a great place to gain experience by young professional members who, after completing their education, can gain industrial experience and continuous access to facilities and support from the university and IES Chapter units.

The preceding example confirms the thesis that fruitful and valuable cooperation between science and industry is possible. The initial collaborations were not easy, and cooperation alone is not always simple. Both sides are constantly reassessing their prejudices and learning to cooperate. Undoubtedly, the keys to success are the willingness to cooperate as well as the visionary and forward-looking attitudes on both sides. The existing measures and possibilities, as well as accepted and developed good practices that allow individuals to solve crises and seek inspiration, have proven to be significant. In this particular case, good practices and initiative, developed as part of IES activities, have been successfully transferred to

FIGURE 5 – A scientific and industrial seminar organized as part of IES Chapter activities. (From left): Prof. Kaźmierkowski, Michał Twerd (chief executive officer of TWERD Power Electronics), Prof. Jasinski, Prof. Malinowski, Prof. Rabkowski, and Piotr Różański (TRUMPF Huettinger).

FIGURE 6 – A joint dinner for academia and industry organized at a 14th-century Gothic castle as part of a series of seminars of PE in renewable energy sources and drives, cofinanced by the IES Chapter.

FIGURE 7 – (a) The global operations and (b) green buildings and green data center established by the Delta Group. (Source: Delta Group; used with permission.)

FIGURE 8 – The Delta–NTUST Academia–Industry Research Center, which is sponsored by the Delta Group and MOST. (Source: Delta Group; used with permission.)

FIGURE 9 – Industry members of the Advanced Power Technology Industry–Academia Alliance, supported by MOST. (Source: Advanced Power Technology Industry–Academia Alliance; used with permission.)

Polish soil, and have had an energizing and growth-stimulating effect (Figure 6).

National Taiwan University of Science and Technology and Power Supply Industry in Taiwan

PE technologies have wide-ranging uses, encompassing national infrastructure and personal electronics. Playing a vital role in global PE technology development, Taiwan has built up competitive advantages in this field with six of the world's top 10 power supply manufacturers based in the country. The impressive achievement is attributable to active devotion on the part of leading enterprises. The Center for Power Electronic Technologies (CPET), led by Prof. Huang-Jen Chiu, Department of Electronic and Computer Engineering, National Taiwan University of Science and Technology (NTUST, so-called Taiwan Tech), has always been a strong technological supporter of the Taiwanese electronics industry. The world's leading power supply company, Delta Electronics, produces 45% of the power solutions for laptops around the globe, with NTUST making critical contributions. Delta Group has 169 sales offices, 37 plant sites, and

69 R&D centers, with over 9,000 R&D engineers throughout the world. From 2006 to 2018, Delta established 27 green buildings and one green data center certified under the Leadership in Energy and Environmental Design program (Figure 7).

Also serving as the dean of the university's Office of Industry–Academia Collaboration (IAC), Prof. Chiu enrolled his team in hopes of developing talented R&D engineers much needed by the industry through joint development efforts with outstanding domestic and international firms. The CPET is among the first research centers NTUST founded. The team is composed of about 200 graduate students, and it not only outperforms the rest of the university's research groups in other fields in terms of team size and technological strength but also is on a par with world-leading academic groups in terms of research scale and abilities. Since 2020, Delta Electronics has established a joint research center at NTUST, with an NT$30 million (US$1 million) budget over a three-year period to enhance Taiwan's industrial competitiveness. Taiwan's Ministry of Science and Technology (MOST) has also granted an award of NT$8 million per year to support the Delta–NTUST Academia–Industry Research (AIR) Center (Figure 8).

NTUST's CPET continues to strengthen its ability to put research achievements to practical use through close industry–academia collaborations. More than 600 graduates have completed their advanced degrees with the CPET's Power Electronics Lab, and they make up a strong workforce leading industry development and research. Aside from incubating talent to meet industry needs, NTUST can also provide global resources in line with partner firms' worldwide strategies to enable win–win situations. For example, many Taiwan-based power supply companies have recruited skilled professionals at their offices abroad through help from NTUST-affiliated schools to help them realize their localization goals.

To further talent incubation and academia–industry collaboration, the CPET also catches industry attention through its ability to develop cutting-edge technologies. An Advanced Power Technology Industry–Academia Alliance, mainly consisting of the CPET and some PE professors' research teams in other universities, has been established and sponsored by MOST to provide a strong service platform for industry (Figure 9). A goal of the alliance is to integrate all PE research energy and service resources to facilitate industry–academia cooperation. By vertically integrating innovative technologies and horizontally implementing cross-domain

FIGURE 10 – A group of Ph.D. students and visitors from On-Semiconductor, one of the industry members of the Alliance. (Source: Advanced Power Technology Industry–Academia Alliance; used with permission.)

FIGURE 11 – The honors and awards received by the NTUST CPET student teams. (Source: NTUST CPET; used with permission.)

exchanges, this industry–academia alliance makes the best use of the resources and energy to advance the practical research conducted in universities and to combine industry's experience and funding to integrate both groups in research and applications to advanced PE technologies (Figure 10).

Several core technologies, including high-power density conversion techniques, green energy technology, lighting technologies and applications,

FIGURE 12 – A collage of international industry–academia activities. (*Continued*)

FIGURE 12 – (Continued) A collage of international industry–academia activities.

motor drive and control, and power integrated circuit design, are provided for alliance industry members. In addition, the alliance can provide counseling and service for industry–academic collaboration projects, technical transfer, human resources development, and professional activities, such as technical conferences, workshops, seminars, and training courses. Alliance operations sustain themselves through membership fees, project administrative fees, technical transfer fees, professional activities, and training courses. Having long supported industry development, the CPET already engages in close collaborations with firms in Taiwan.

In 2013 and 2015, NTUST CPET student teams won the grand prize at the IEEE International Future Energy Challenge (Figure 11). In 2015, Google gave grants to the 10 top university teams for research on high-power density PV inverters. The CPET was one of the recipients of the Google Little Box Academic Awards, which came with a US$30,000 award. In 2018, the CPET student team also won the IEEE Empower a Billion Lives Pacific Asia Regional Award. Prof. Chiu served as the chair of the IES Taipei Chapter during 2015–2016 and as secretary of the IEEE PELS/IES Taipei Joint Chapter during 2010–2014.

The CPET organized and/or co-organized many international industry–academia activities, including the IES Taipei Annual Forum; the Green Energy Electronics Forum; the 2015 IEEE International Future Energy Electronics Conference; the 2014 Symposium on Semiconductor Power Conversion cosponsored by IES/PELS Taipei, the Korean Institute of Power Electronics, and the Institute of Electrical Engineers of Japan (IEEJ) and Industry Applications Society (IAS) in Japan; the 2012 Taiwan–Japan Symposium on Power Conversion, cosponsored by IES/PELS Taipei and IEEJ and IAS in Japan; and the 2015 Cross-Strait Green Energy Forum cosponsored by the Taiwan Power Electronics Association and the China Electrotechnical Society (Figure 12).

Operating in the spirit of "practice-oriented education," NTUST is acknowledged as a leading pioneer among technologically advanced universities in Taiwan. It provides innovative and key technologies to the global market. The IAC Office is in overall charge of industry–academia–government cooperation, innovation, and promotion of Taiwan Tech. Through a single service window, the IAC Office provides and integrates interdisciplinary resources to accelerate, expand, and promote the development of international connections. With a global perspective, innovation, and entrepreneurship as the ultimate goals, the IAC Office can maximize the synergies between industry and academia.

A Global Research & Industry Alliance (Taiwan Tech GLORIA) in the IAC Office has been supporting NTUST's research and is dedicated to integrating an industry–university–government high-tech ecosystem under one roof to boost beneficially bilateral and multilateral cooperation in cutting-edge technology fields (Figure 13). Taiwan Tech GLORIA provides a "one-stop consulting service" to alliance members and customized

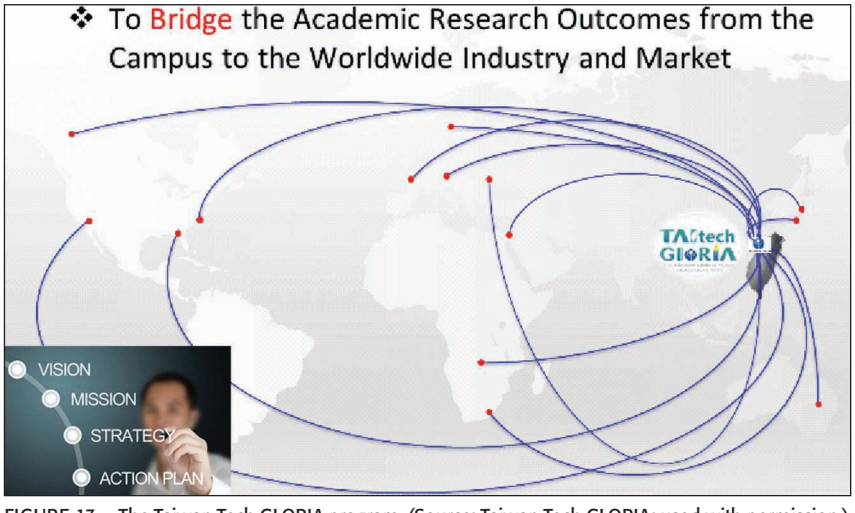


FIGURE 13 – The Taiwan Tech GLORIA program. (Source: Taiwan Tech GLORIA; used with permission.)

marketing service programs based on their needs to minimize initial barriers of entry and help them to uncover new opportunities. With a commitment to promoting collaboration between university and industry, Taiwan Tech GLORIA will continuously play a vital role and devote itself to meet the needs of faculty research teams and corporate partners to accelerate advances in technology and knowledge discovery.

NTUST has been devoted to promoting joint industry–academia development and talent incubation but has delegated the work to individual research teams. Going forward, NTUST will continue to operate using the collaborative model wherein each party is dedicated to tasks in which it specializes. This benefits both industry and academia as NTUST endeavors to educate first-rate talent and develop cutting-edge technology.

Conclusion

It is evident that, thanks to IEEE contacts and e-ways, we can prepare a better world for hi-tech industry based on well-educated students and young professionals. We are trying to do our best.

It is also good to point out that our sister Society PELS provides free access to all past PELS webinars and slides in their resources [21]. Among other excellent materials, you will find "High Power Density Converter Design with Wide Bandgap Devices" by Prof. Chiu. Indeed, because of difficulties caused by the pandemic, we will provide free access via the Internet to our educational information to help each other and society.

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Chapter News

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FIGURE 2 – Classes at the European Ph.D. School were hosted in the majestic Angevin Castle in Gaeta, Italy.

the IEEE Industrial Electronics Society. This represents the beginning of an important collaboration that will be beneficial and strategic for the entire scientific and industrial community. More information about the European Ph.D. School can be found at www.phd-school.org.

The 21st European Ph.D. School was hosted 25–29 May 2020 at Angevin Castle, in cooperation with the European Center for Power Electronics.