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Thirteenth Annual ECCE Delivers the Latest Innovations in Energy Conversion, Electric Machines and Drives

ECCE
INNOVATIONS

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In a virtual format

by Ashok Bindra, Mark Scott,
and Jean-Luc Schanen

This year, the thirteenth annual IEEE Energy Conversion Congress and Exposition (ECCE) 2021 was an all virtual event. Cosponsored by the IEEE Power Electronics Society (PELS) and the IEEE Industry Applications Society (IAS), this flagship event presented the latest in energy conversion, electric machines and drives, applications, and engineering tutorials. Setting new records in virtual attendance, the ECCE 2021 organizing team, led by the general chair Giovanna Oriti of Naval Postgraduate School, USA, delivered an exciting program comprising enlightening plenary talks, inspiring special sessions, educational technical papers, informative industry panel discussions, entertaining social events, and instructive

tutorials combined with a virtual exposition demonstrating state-of-the-art products and technologies.

The conference opened on Sunday 10 October with a tutorial program in a virtual format. Because of the virtual format, participants were able to access the tutorial presentations a few days earlier so that they could get the most out of the live sessions with the tutorial presenters on Sunday. The topics included grid-forming technology, wide bandgap devices, electric machine design, electric drives, solar photovoltaic and energy storage systems, design practices, electro-magnetic-interference, resilience, reliability and electro-thermal design.

Plenary Talks

On Monday, 11 October, the program started with four plenary talks by experts and leaders from Tesla, magniX, General Electric Aviation, and Intel, who presented the latest

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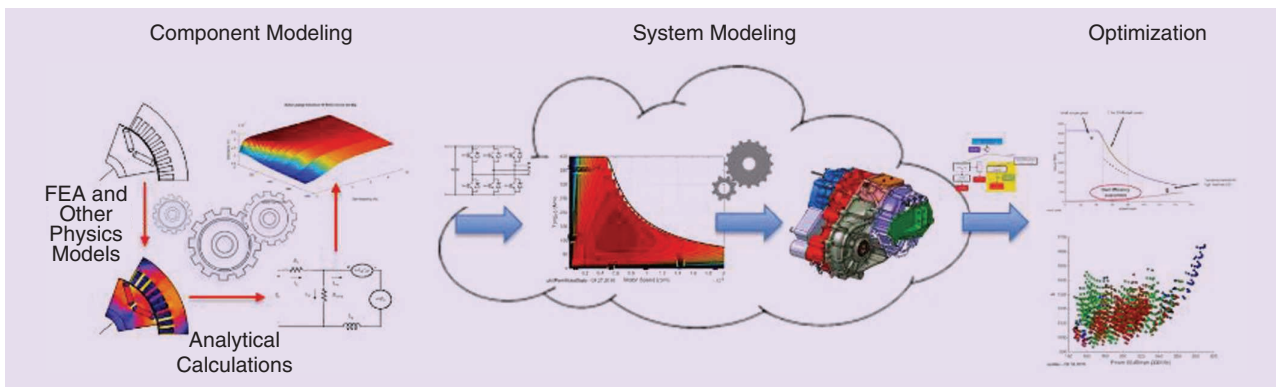


FIG 1 Advanced modeling is needed to optimize the performance of electric motors.

energy conversion technologies and their visions for future research and development. Plenary speakers were introduced by session chair Sara Roggia of magniX. Tesla's principal motor designer Dr. Konstantinos Laskaris kicked-off the session with a presentation titled "Motor Technology Selection and System Level Optimization Effects in Drive Systems." In essence, Dr. Laskaris' talk focused on key characteristics of motor, inverter and gears to achieve optimal design with particular focus on the motor technology. He indicated that electric vehicles (EVs) have evolved significantly in the last 10 years and motor technology has played a key role in delivering the improved performance. Developing a motor that offers high-speed, efficiency, density and other such performance metrics is not a trivial task. It is a combination of several factors including methodology, engineering tools, modeling and more. He added, "true optimal design constitutes an important competitive advantage in EVs and requires good knowledge of physics modeling, parametric design, numerical simulations, and decision making." Battery, motor, inverter and gear design space is examined during the optimization process. Moreover, he continued, higher speed, compact systems, exhibit dominant high frequency losses, introducing the need for advanced modeling to capture the phenomena (Figure 1)." He also emphasized the fact that materials play an important role in the development of high performance motors.

The second plenary speaker was magniX CEO Roei Ganzarski, whose talk "Concept to Reality: The Journey of Electric Aviation" investigated the journey from a new entrants' perspective. Ganzarski's presentation highlighted the challenges, pitfalls, and successes in taking electric propulsion and aircraft from concept to reality. He discussed practical real-world lessons that should be considered when taking on such intrepid goals. In summary, he described nine steps that an entrepreneur must take in order to become an electric aviation company. These include design, source, integrate, test, fly, certify, finance, policy, and market. Testing was a key component of the process as it would ensure safety and reliability in the air. "Safety rules in aviation are stringent," noted Ganzarski.

Initially, like EV maker Tesla, according to the keynoter, the company took the electric retrofit route. To transform

popular utility planes into all-electric aircrafts, magniX retrofitted De Havilland Beaver seaplane with a magni500, 750-horsepower (HP) EPU in 2019, and in 2020 powered a 208B Cessna Grand Caravan with a 750 HP magni500 propulsion system. "This fantastic work by magniX team has resulted in a NASA project to demonstrate electric propulsion technologies for aircraft," noted Ganzarski. The NASA project is worth US\$74.3 million and is being made through NASA's electric powertrain flight demonstration program (EPFD) (Figure 2). Through the EPFD program, NASA is planning to introduce electrified aircraft propulsion technologies to U.S. aviation fleets by 2035.

Next, GE Aviation's hybrid electric systems leader Christine Andrews gave a presentation on "Hybrid Electric Systems for the Commercial Aviation Sector." In this presentation, she indicated that GE Aviation is committed to a more sustainable future of flight and hybrid electric is the way to achieve it. In fact, GE Aviation is one of the two U.S. companies that NASA has selected to support its EPFD program that will rapidly mature electrified aircraft propulsion technologies through ground and flight demonstrations. "To enable the aviation industry reach its decarbonization goal, the jet engine maker is pursuing hybrid electric capability for single-aisle aircraft," noted the speaker. According to Andrews, "Single-aisle air transport is the largest civil aviation market, where emissions-reducing technologies would have a major impact." Continuing, she added that hybrid systems will evolve for the next few decades. In essence, GE has projected four phases of development (Figure 3). Currently,



FIG 2 NASA selects magniX to develop electrified aircraft propulsion technologies. Source: NASA.

continued Andrews, “we are under phase1 of development and electric propulsion technology will target low power aircraft application.” Beyond 2025, phase2 will see hybrid systems used in smaller aircrafts with demonstration in larger applications,” said the keynote speaker. Likewise, beyond 2030, phase3 will enable single aisle aircrafts with hybrid electric capability to enter service. Finally, as per the chart in Figure 3, Phase4 will begin after 2035 and is projected to further advance electrification concepts. Andrews presentation also provided an overview of new opportunities and challenges for making hybrid electric systems a reality for the commercial aviation sector. They include:

- Aircraft integration
- High voltage power distribution
- Integration of gas turbines with electrical components
- Thermal management
- Energy storage revolution
- Certification

Finally, Dr. Irene J. Petrick, senior director of industrial innovation in the Internet of Things group at Intel, talked about driving digital transformation. Investigating this transformation, her talk primarily focused on the interplay of people, processes and technology. Consequently, Dr. Petrick explored external factors driving this transformation. In reality, Dr. Petrick’s presentation revealed lessons learned from Intel’s four-year study of over 500 people at more than 400 companies. It is well understood that Industry 4.0 harnesses digital tools to make industrial operations smarter, more efficient, and ultimately to operate autonomously. Consequently, she noted that data plays a key role in this transformation with an ability to drive proactive decisions. To accelerate the digital transformation journey one needs both a long term vision and a digital architecture. “It’s not just applying digital tools to current operations. Instead, successful companies have had to rethink complex interactions between people, processes, organizational culture and technology,” concluded Dr. Petrick. In her closing remarks, Dr. Petrick, indicated that the future is here and that the intelligent factory may be closer than you think.

Virtual Exposition and More

Soon after the plenary session, virtual exposition was officially launched. The exposition was open for next two days and about 32 companies demonstrated their cutting-edge components and systems for a wide range of applications. While STMicroelectronics was a gold sponsor of the event, OPAL-RT Technologies participated as a silver sponsor. Other well-known exposition participants included Infineon Technologies, Wolfspeed, GeneSiC Semiconductor, Efficient Power Conversion Corp. (EPC), MathWorks, Plexim, Vicor, Rohde & Schwarz USA, Inc., Magna-Power Electronics, Payton America, and Magnetics to name a few. Besides live virtual exposition, there were exhibitor product sessions where exhibitors discussed their latest offerings. STMicroelectronics, for example, took a closer look at evolution of power delivery for cloud computing. In this session, ST’s product marketing manager Jeff Halbig examined a variety of power delivery topologies, ranging from ac-dc to point-of-load, that were leveraging ST’s wide product portfolio, including the latest innovations in GaN transistors and drivers. Aside from discussing integrated MasterGaN devices for high-efficiency power conversion applications, Halbig also introduced VIPerPower and VIPerGaN45, an integrated ac-dc converter with low $R_{DS(on)}$ 650 V power GaN HEMT. Likewise, OPAL-RT Technologies’ field application engineer Bowen Liang demonstrated hardware-in-the-loop (HIL) tests for low voltage ride through (LVDT) capability of solar energy inverters using an FPGA-based real-time simulator. Another interesting demonstration came from GeneSiC Semiconductor. The company’s application engineer Sumit Jadav disclosed its next generation 1200 V G3R SiC MOSFET with $R_{DS(on)}$ ranging from 20 m Ω to 350 m Ω , offering unprecedented levels of performance, robustness and quality.

Adopting live format similar to the plenary session, several special sessions provided attendees the opportunity to participate in panels with experts from industry and academia. The topics were very timely and important, ranging from additive manufacturing for electric machines to wide bandgap (WBG) devices, and future electric grid. Speaking



FIG 3 Evolution of hybrid propulsion systems in next few decades.

of WBG devices, there was a special session on medium and high-voltage GaN power devices. In this session, Dr. Dinesh Ramanathan, CEO of NexGen Power Systems, described a robust 1200 V GaN device based on vertical GaN structure and then demonstrated its use in building a 240 W PFC corrected high efficiency, high density power conversion system. Other researchers presenting their respective work in this area included Dr. Tohru Oka, project general manager at Toyoda Gosei, Dr. Robert Kaplar, manager of the semiconductor material and device sciences, Sandia National Laboratory, Dr. Tamara Baksht, CEO, VisiC, and Dr. Juan Sabate, senior principal engineer, GE Global Research Center.

More Technical Presentations

892 final papers were included in the ECCE 2021 technical program. The technical program committee decided to take the opportunity of the virtual format to offer all authors the same way of delivering their paper, using a 20 minute prerecorded video: contrary to in-person conferences, the number of parallel sessions is not limited, since the content is available on demand on the virtual platform, for 30 days. Consequently, 160 sessions of 5-8 papers were offered to attendees. Two sessions (E07 and I01) were named in memory of Prof. Akira Nabae and Prof. Braham Ferreira, who passed away recently, and included a specific video as a tribute to their outstanding careers and many contributions to IEEE Power Electronics Society (Figure 4).

The tradition of student project demonstration is still strong, with some 20 projects engaged in both hardware and software competition in ECCE2021. This initiation to research can lead to very nice results, as illustrated by a technical paper in Topic E (Power Converters Topologies). Indian Institute of Technology Kanpur presented their IEEE International Future Energy Challenge (IFEC) 2020 [1] entry at ECCE 2021 as part of the proceedings. They built a multiport power supply for nano-satellite applications. The constraints were two inputs for solar panels, a bidirectional battery port, and two outputs. They developed a unified control strategy for the converter, and created a novel bootstrapping technique to drive the upper power devices in the converter. The 60-W prototype met, or exceeded, all of the IFEC 2020 benchmarks and earned the team The Ingenuity Award [2].

In addition to the technical program, the virtual conference featured 25 live or simulive special sessions, strongly oriented towards the latest industrial interests and technology trends. It is worth noting that the content of these Special Sessions is very often aligned with the “hot topics” of the Technical Program. For instance, the special session “P2964 IEEE Standard for Datasheet Parameters and Tests for Integrated Gate Drivers”, organized by Dr. Tanya Gachovska, MDA, Canada, is in line with not less than three technical sessions on Gate Drivers in Topic I (Power Semiconductor Devices). Also, WBG is still an important theme, with four tutorials related to their usage or characterization, a number of technical papers and three special sessions:

- Wide-Bandgap Bidirectional Switches and the Applications They Enable, organized by Dr. Thomas M. Jahns, University of Wisconsin – Madison, and Dr. Victor Veladlis, North Carolina State University
- Future of Wide-Bandgap Devices SiC, GaN and Diamond and Their Emerging Applications in Power Electronics, organized by Dr. Tanya Gachovska, MDA, Canada.
- EMI and Insulation Related Challenges and Solutions for WBG -based Power Electronic Systems, organized by Bulent Sarioglu, Associate Professor, University of Wisconsin, and Jin Wang, Professor, Ohio State University.

Beside converter topologies (Topic E) and control, modeling and optimization of power converters (Topic F), which are two pillars of ECCE (54 sessions, one third of the technical program), a consistent theme for several years in ECCE is the wireless power transfer (WPT). Topic K (Emerging Technologies), had 22 papers dedicated to this subject. Researchers from Okayama University, Japan, develop a method that improves the performance of multiple-transmitter WPT. K. Matsuura et al. [3] introduced a method that mitigates the issue of stray interactions between them. They use two control variables: phase-shifting between switching legs, to regulate the output voltage of the inverter and reactance control, to eliminate cross-interference. The authors provide experimental results to validate their approach.

In the field of energy conversion, ECCE is also focusing on electrical machines (Topic G), drives (Topic H) and transportation (Topic D). The evolution of the technology associated with electrical machines has been underlined with three special sessions organized by both academia

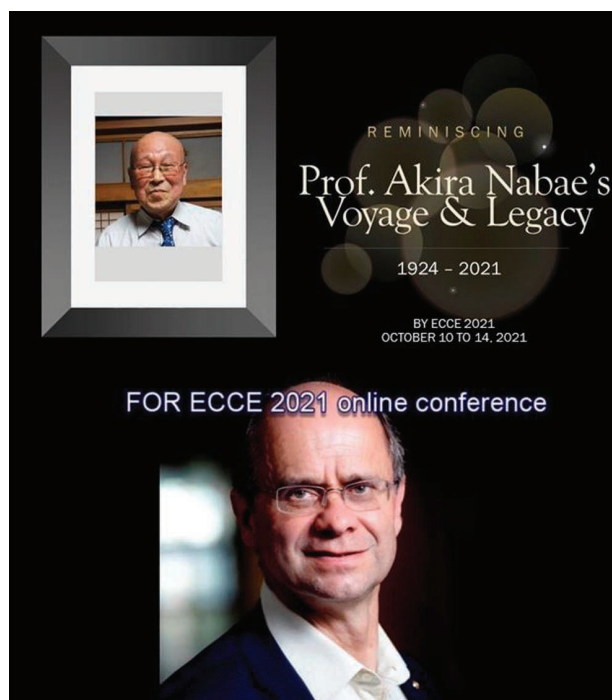


FIG 4 Two videos specially produced for ECCE on line conference, in memory of Prof. Akira Nabae and Prof. Braham Ferreira.

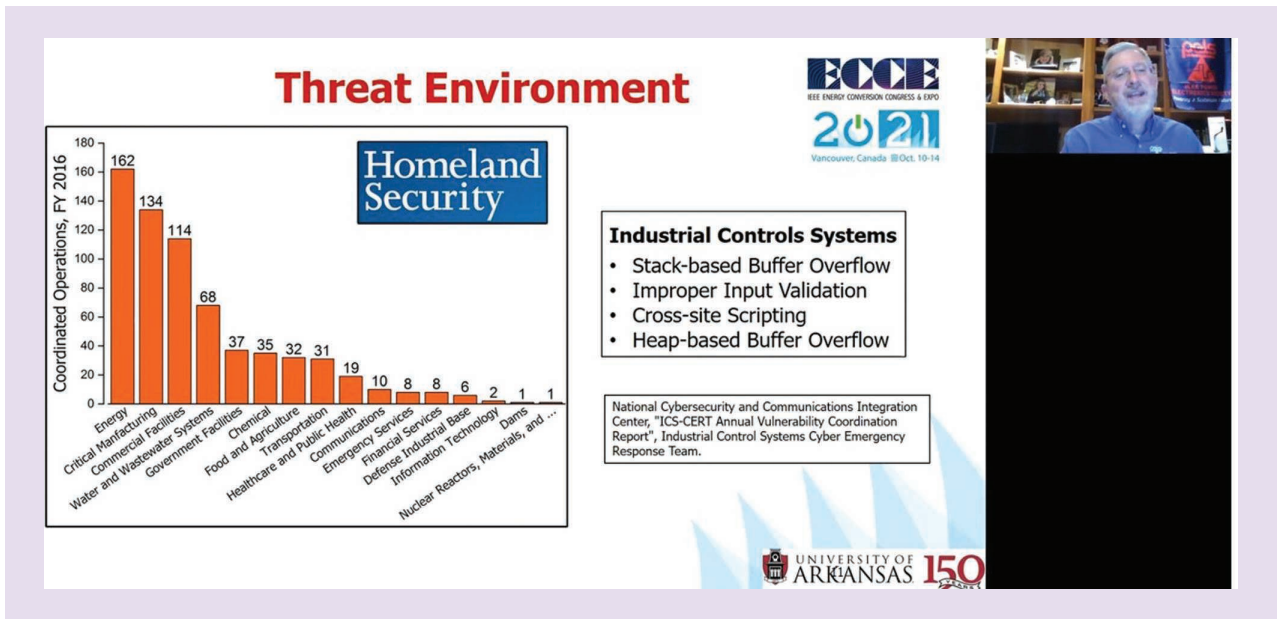


FIG 5 Energy in the pole position of critical infrastructures regarding cyberattacks!

and industry (Franco Leonardi and Leyi Zhu, Ford Motor Company) with a focus on additive manufacturing, also used for power electronics (Bulent Sarlioglu, University of Wisconsin, Ayman El-Refaie, Marquette University, Will Sixel, NASA Glenn Research Center in Cleveland).

The “system level” vision is also a core topic of ECCE. Renewable, smart grids, microgrids (Topics A, B) have been illustrated with 11 special sessions, two of them focusing on storage (Dr. Tu Nguyen, Sandia National Laboratories, and Juan Carlos Balda, professor, University of Arkansas). With energy being a critical resource for industry and population, it has been acknowledged as the 5th domain of warfare (after air, land, sea, space), and cybersecurity becomes a major concern (Figure 5). The special session “Cybersecurity for Power Electronics”, organized by Alan Mantooth, University of Arkansas; Frede Blaabjerg, Aalborg University and Sudip Mazumder, University of Illinois, Chicago, made a complete overview of possible attacks and consequences, ... and fortunately made some recommendations!

Thanks to the dedication and hard work of the organizing team, the ECCE 2021 delivered a memorable virtual event that catered to the needs of attendees from around the world. From tutorials to latest products across the board, the conference provided a stimulating program, along with a lively virtual exposition, that offered five days of excitement.

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