TRANSFORMERS MAGAZINE

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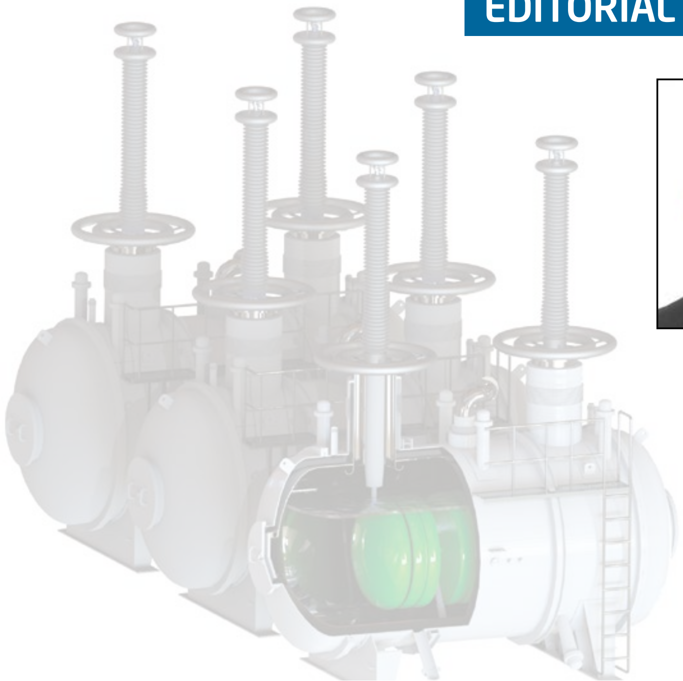


Dear Readers,

While the domain covered by Transformers Magazine is, naturally, the transformer industry, technology and market, as a reference publication we also cover areas and technologies that may not be extremely important at the moment, but they might have a more pronounced impact on our industry in the near future. One such area is superconductivity. In the past, some transformer manufacturers and other scientific research institutions have made significant investments in superconducting transformers, and a lot of knowledge and experience has been gathered through such scientific research projects. However, due to certain limitations, this technology is still not cost-effective for wider application.

On the other hand, the development of superconducting materials is not slowing down. Today, under certain conditions, superconductors carry 100 to 500 times higher current compared to copper with almost no loss, so it is only a matter of time before we reach the breaking point at which superconducting transformers will become cost-effective. This technology will initially include special application, perhaps in traction transformers or reactors, or maybe in fault-current limiters, aviation, or something else, but nonetheless, the time of superconductivity is slowly but surely coming along.

Five years ago, we published the results of a research project titled Superconducting transformers - Part I and II (Transformers Magazine volume 3, issue 2 and issue 3, 2016), and now, five years later, we wanted to refresh the information in this area. This time, the interest in this topic was considerable, so we gathered a great editorial team led by Dr. Mohammad Yazdani Asrami, Deputy Editor-in-Chief for this edition, and an excellent line-up of authors that helped us prepare an entire edition dedicated to superconductivity.

Considering the wider importance of this technology, we have not limited ourselves to topics related to transformers and reactors, but have, nevertheless, included fault current limiters, cables and superconducting materials.

I am extremely grateful to all editors, reviewers, and authors for taking part in this edition which abounds in top quality materials. In the hope that you will find the information we bring to you useful, I wish you a joyful reading!

Mladen Banovic, Editor-in-Chief

Forewords to the Special Edition

Estimating that the global electricity demand will be growing 2.1 % per year to 2040, many different interventions including operational, technological, as well as policy and investment-based decisions are needed to make modern power systems - one of the most important infrastructures in modern society - more flexible, more reliable, more resilient, more compact, more efficient, and more affordable. With this ever-increasing load demand in the modern society, energy loss values, efficiency rates, reliability, and short circuit level of the power network are major concerns. On the other hand, there are environmental issues that utilities or network operators need to address, including price of land, CO2 footprint, and concerns related to oils used in the apparatus or their recycling after the end of life. In addition, climate change and global warming concerns will make production of the traditional conductors very expensive over the next two decades, as their production is linked with mining activities, and then proper purification process which are both sources of pollution. Therefore, these issues raise a strong need for game-changing dramatical solutions to decrease losses, reduce environmental footprint, increase efficiency and reliability. Cryo-electrification of the power system that takes advantage of cryogenic and superconductivity technologies would be this game-changer. Superconductors with their much higher current density, near zero resistance, and almost loss-free performance seem to be a viable solution for the replacement of the conventional conductors such as copper and aluminium. Superconductivity is a phase of material at cryogenic temperatures - in some specific metals or alloys - which can be defined with three critical limiting factors, i.e., critical temperature, critical current density, and critical field. Superconductors carry 100 to 500 times – depending on operating condition - higher current compared with copper, almost with no loss if they work within the three aforementioned limits.

Applied superconductivity offers huge opportunities for optimization and modernization of whole energy and power systems for making it more efficient, compact, smarter, reliable, lighter, sustainable, and environmentally friendly by using physical essence and attribute of superconductors and implementing them into the products. The success of superconductivity, however, depends on the overcoming challenges such as initial purchasing cost, as well as technical issues. The power transformers, power cables, and fault current limiters are the most important conventional apparatus in the power network so that their replacement with superconducting versions sound promising.

Some of the technical challenges that need to be addressed in the current decade are as follows:

- Superconductor manufacturing issue of producing longer length of tapes / wires,
- Tape / wire final price,
- Discovery and fabrication of superconductors with a higher critical temperature,
- Invention of new or improvement of existing cryocoolers and cooling systems,
- Overcoming technical issues in design and development of superconducting devices.

I believe that working on the following topics would be part of the roadmap for superconductivity in power network or transportation applications:

- Focusing on manufacturing of cheaper wires / tapes
- Application of artificial intelligence for smarter manufacturing and condition monitoring of superconducting devices,
- Integration of magnesium diboride into superconducting devices,
- Using new coolants such as hydrogen for making the free cooling systems where possible, especially in renewable energy plants,
- Integrating DC power cables in long HVDC transmission lines,
- Additive manufacturing for faster, more precise, and smarter manufacturing of superconducting devices,
- Recycling of superconducting components and devices.

This special issue aims to provide a forum for the latest developments, future plans, and long-term roadmap for superconductivity in power grid applications. The focus was on the achievements of superconductivity-based technological developments, and applications in transmission, and distribution of electricity, fault current limitation, loss evaluation, feasibility studies. Topics ranged from an individual device to integrated systems.

All the papers published in this special edition underwent stringent single-blinded peer-review process involving a minimum of two reviewers comprising internal (editorial board of the magazine) as well as external referees. This was to ensure that the quality of the papers justified the high expectation of Transformers Magazine editorial board, which is renowned as one of the most important technical magazines on the topic in the world. We thank the authors for agreeing to publish their papers in this special edition, and the guest editors and reviewers involved in the publishing process of these papers.

We hope that this special edition will shed a light on the disruptive innovation in the field of applied superconductivity that is expected to change and modernize the future power networks. In addition, we aim for motivating the utility and power network stakeholders to invest in the applied superconductivity and cryo-electrification for reaching to this modernized future network.

Dr. Mohammad Yazdani-Asrami,
Deputy Editor-in-Chief for Special Edition Superconductivity

Mohammad Yazdani-Asrami, Deputy Editor-in-Chief

Mohammad Yazdani-Asrami holds a Ph.D. degree in Electrical Power Engineering. He spent the last 12 years on research works and projects related to transformers, electric machines, and harmonics in four different countries, including Iran, Italy, New Zealand, and the UK. He worked on a project for the design development and fabrication of a fault-tolerant superconducting transformer at Robinson Research Institute, Victoria University of Wellington, New Zealand, which this transformer holds the world record on fault withstanding time for HTS transformers. He is currently with the Department of Electronic and Electrical Engineering, University of Strathclyde, Glasgow, United Kingdom. Dr Yazdani-Asrami's current fields of interest are cryo-electrification for modern transportation and applied superconductivity for large-scale power applications, including superconducting transformers, fault current limiters, rotating machine, and cables. He is a member of IEEE (MIEEE), member of IET (MIET), member of British Cryogenic Council (MBCC), member of Cryogenic Society of America (MCSA) and an editor at Transformers Magazine (TM).

Hyukchan Son

Mr. Son is a Senior Manager of KEPCO (Korea Electric Power Corporation) who leads the Team of Power Grid Device, making the overall plan to the use of technologies within KEPCO. *(KEPCO is a representative utility company which has several subsidiaries and affiliated companies.)*

He began his career at KEPCO where he has been actively involved in various projects, businesses, research work and development. He has played many of the great roles in applying new technology systems to Korean power grid, such as eco gas insulated switchgear, high efficiency transformer, superconducting materials and related technologies, etc.

Before joining Power Grid Device, Mr. Son has made his utmost efforts to create a corporate culture that pursues hand-in-hand growth with domestic small and medium-sized companies by sharing of KEPCO's outcomes.

Sergey Samoilenkov

Sergey Samoilenkov's main fields of expertise are applied superconductivity, cryogenic insulation, and power grid equipment. He graduated from Chemical Department of Moscow State University in 1996. In 1999, he received a PhD in chemistry for a thesis on high temperature superconductors. In early 2000s, he worked as a scientific staff at TU Braunschweig, Germany. Being a CEO of SuperOx company since 2013, Dr. Samoilenkov made a significant contribution in promoting the use of superconductor technologies in the real power grid, in particular, applying the first 220 kV superconducting fault current limiter in Moscow.

Weijia Yuan

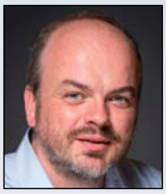
Professor Weijia Yuan received his Bachelor degree from Tsinghua University and his PhD from the University of Cambridge. He then became both a research associate in the Engineering Department and a junior research fellow at Wolfson College both at the University of Cambridge. Dr Yuan joined the University of Bath as a Lecturer/Assistant Professor in 2011, where he was later promoted to Reader/Associate Professor in 2016. He joined the University of Strathclyde as a Professor in 2018.

He is now leading a research team of 15 researchers in the area applied superconductivity including energy storage, fault current limiters, machines and power transmission lines. He has been working closely with industry partners on all electric propulsion for future electric aircraft, designing a fully superconducting system for aerospace application. His work also involves renewable energy integration and power system stability using energy storage systems.

Professor Yuan's achievement in Engineering and Physics have been recognised as being awarded the Fellowship by both the Institute of Engineering and Technology and the Institute of Physics.

Zhenan Jiang

Zhenan Jiang received a B.Eng. in Electrical Engineering from Chongqing University in Chongqing, China in 1994, and M.Eng., Ph.D. Eng. in applied superconductivity from Yokohama National University in Yokohama, Japan in 2002 and 2005, respectively. He was a Postdoctoral Research Fellow at Yokohama National University from 2005 to 2008. He joined the Superconductivity Group currently known as the Robinson Research Institute at Victoria University of Wellington, New Zealand in 2008 as Research Scientist. He has a strong track record in characterization of high temperature superconductors (HTS), especially in AC loss and has published more than 100 SCI papers. He is now Principal Scientist and is leading AC loss research in the institute. His recent research interests include AC loss characterization in HTS coils, transformers, flux pumps, magnets, and rotating machines. Dr. Jiang has been twice awarded the JSPS (Japan Society for the Promotion of Science) invitation fellowship to Kyoto University under the NZ-Japan Scientist Exchange Program, in 2011 and 2015, respectively. He is currently a visiting professor of Beijing Jiaotong University, and was elected as a senior member of IEEE in 2019. He is currently supervising two PhD students.



Dr Arnaud Allais

Dr. Allais holds an engineer degree in Energy and Materials, and a PhD on the modelling of the manufacturing of high temperature superconductor (HTS) tapes. In charge of the development of HTS materials and HTS cables, he has been deeply involved in different key projects, e.g., the first high voltage HTS cable energized in the grid on Long Island in 2008 (138 kV – 600 m) as well as the first HTS coated conductor based MV cable in Europe (Super3C). From 2008 to 2019, he joined the Corporate Research Teams of Nexans and was for some years director of the Nexans Research Center in Lyon.

Since the beginning of 2020, he has been in charge of the business development of HTS solutions within the Cryogenic and Superconductors unit of Nexans. In April 2021, Arnaud was appointed by the IEC Standardization Management Board as the new Chairman of IEC Technical Committee TC 90 on Superconductivity.