Bulletin Board

Report on the 2022 IEEE DEIS Summer School in Monmouth, Wales

Introduction

From August 21 to 25, 2022, the sixth annual IEEE DEIS-sponsored Summer School on Extra-High Voltage DC (EHVDC) Transmission took place in Monmouth, located on the border between England and Wales, UK. Unfortunately, the summer school was not spared from the COVID-19 pandemic, which, as many of us know, has become a constant companion in our everyday lives. As a result of some cases of illness among the moderators and speakers, the summer school was quickly adapted into an all-too-familiar hybrid event. However, this made it possible for all participants to attend all presentations, network, and exchange ideas in the best way possible, while also staying safe.

The objective of this year's summer school was to organize brainstorming sessions among young researchers that revolved around challenging topics in the field of EHVDC transmission and in the field of dielectrics and electrical insulation. This included the discussion of research methodologies and support for the creation of research networks and aimed to stimulate subsequent activities, possibly including joint research work, presentations, and special sessions at future IEEE DEIS conferences. The summer school was accessible for PhD students, early-career postdoctoral researchers, and early-career engineers working in the industry. Overall, there was a total of 28 participants and 5 moderators, forming an international gathering from Austria, France, Greece, Italy, India, Sweden, Switzerland, the UK, and others. The summer school was led by Thomas Andritsch, John Fothergill, Peter Morshuis, Istebreq Saeedi, and Alun Vaughan. This report was written by this year's participants for the wider IEEE DEIS community and provides a summary of this year's summer school.

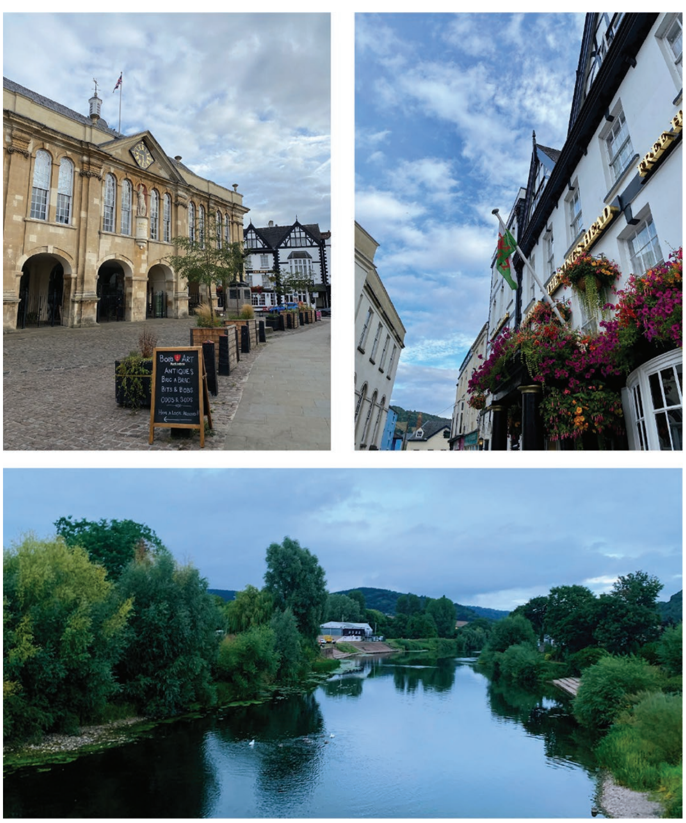

Figure 1. Highlights of Monmouth: Shire Hall, the Kings Head Pub, and the River Wye.

To meet the global net-zero targets, the current quest to simultaneously increase electrification and decarbonize has stimulated a plethora of technological initiatives, both in academia and in industry. HVDC transmission, which facilitates the remote connection of load centers to renewable energy sources, such as hydroelectric, wind, and solar, has received significant attention and is becoming increasingly widespread. The benefits of HVDC over traditional HVAC include aspects such as controllability, high efficiency, ability to be transmitted over greater distances, flexibility to transmit between systems operating at different frequencies, absence of the skin effect in conductors, and lower environmental impacts [1].

HVDC transmission primarily employs two technologies: overhead conductor-based lines, and cables [1]. Typically, transformers are used for long-distance terrestrial power transfer. Comparatively, cables need fewer transmission line corridors and offer a wider variety of uses, including subterranean and underwater power transmission. Furthermore, it allows the

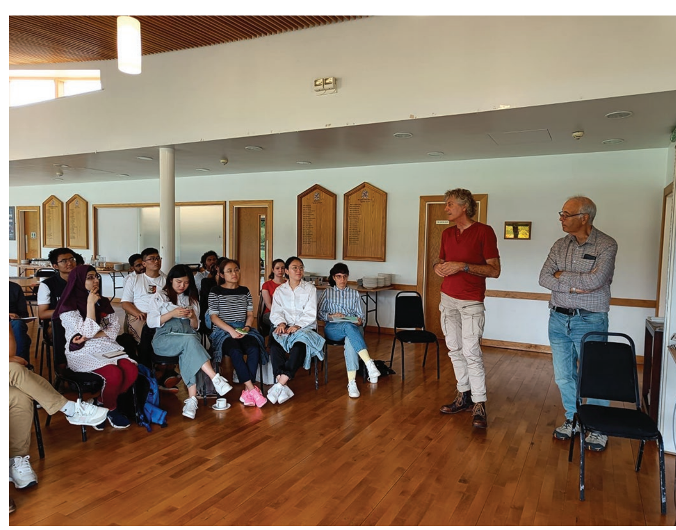

Figure 2. First session with Peter Morshuis (left) and John Fothergill (right).

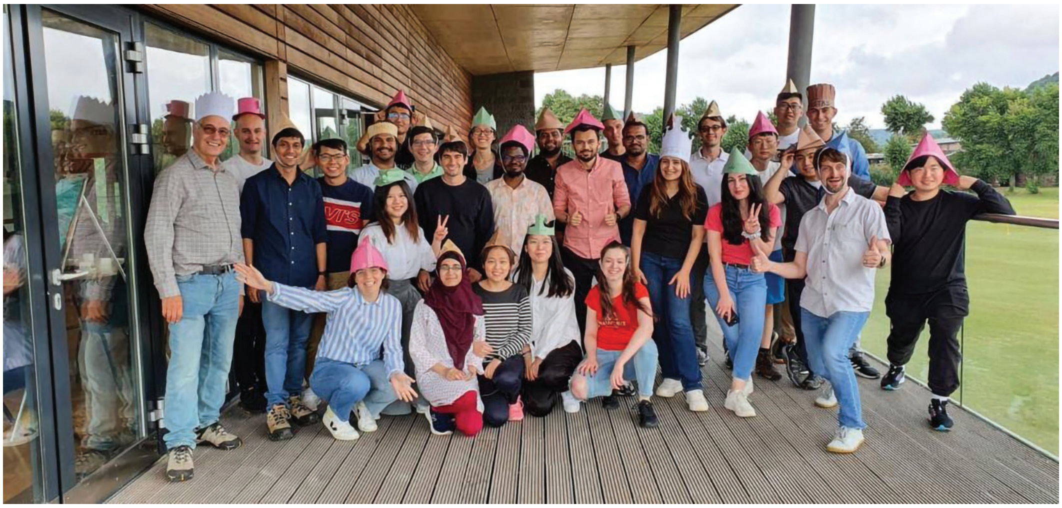

Figure 3. Participants (and organizers) with their thinking hats.

integration of offshore renewable energy sources [2]. Current HVDC insulated cables may be separated into mass-impregnated (MI) and extruded DC cables [3]. MI cables have several issues, including expensive installation and maintenance costs, complex production and maintenance procedures, and low working temperatures, and are potentially environmentally polluting [2]–[4]. Therefore, HVDC extruded cables have further been identified to be the predominant alternative for HVDC transmission, owing to their advantages associated with maintenance, lower cost, and the ease of installing accessories.

However, a number of issues currently impede the mass adoption of HVDC transmission technology, which could be largely ignored in the HVAC case. These issues revolve around the role of field- and temperature-dependent conductivity, insulation temperature, space charge accumulation, and aging. These pressing issues therefore formed the basis of discussion for this session of the IEEE DEIS summer school.

Over the course of the summer school, participants were led by the instructors with the goal of developing research proposals relevant to EHVDC transmission. To achieve this, participants were split into groups and, over the days which the summer school took place, were progressively provided with three different strategies to work with. The first was the six thinking hats decision method, in which each member of the group was provided with a colored paper hat that defined their role. For example, red "emotion" hats would express their raw feelings toward the research question under consideration, green "ideas" hats would recommend new ideas and concepts to improve the proposal, and brown "negative" hats would take a pessimistic stance and consider the hurdles that may appear when implementing the research in question. This strategy helped participants to consider the problem from every perspective, brainstorm, and bring fresh ideas to the table.

The next concept that was introduced was SMART thinking, based on the requirement that a research question should be Specific (are the objectives clear in scope, with no ambiguity?), Measurable (can the researcher measure the output?), Attainable (is it plausible, given constraints and limitations?), Relevant (is the research important and desirable?), and Timely (can it be achieved in the time available, has it been done before?). Altogether, applying the SMART criteria to a proposed research question can help to ensure that the question is well-posed, which may ultimately save both time and effort in the long run. Participants were first given example questions to collectively evaluate against the SMART criteria. This led to insightful discussions about what makes a research question SMART. This same thinking was then applied to the groups' own research questions, with valuable peer feedback given to each team. There was a marked difference when comparing the original research questions to their refined counterparts, before and after SMART was applied.

Last, the groups were introduced to the idea of known knowns, known unknowns, unknown knowns, and unknown unknowns and subsequently to the concept of effective research hypotheses. From this perspective, a research question is a known unknown, and a hypothesis is a research question that also includes the predicted result. Participants learned that hypotheses should be specific and quantifiable, for example: "Increasing the system voltage by 10 kV, will increase the ampacity by 20%." Therefore, they are useful as a guide, to ensure that the proposed research is testable and that the research objectives are achievable.

The combination of these three tools provided by the instructors led to the successful development and refinement of research proposals for each team. These have been summarized by each team below.

Group Proposals

Group A—Juliana Beça, Fabian Bill, Sofia Mavidou, Rohith Sangineni, Adeep Santosh, and Kai Zhang

The research topic chosen by this group within the HVDC domain was concerned with XLPE cables. This was a topic that interested all group members, as it overlapped with everyone's individual research work. After engaging in discussion regarding the research focus, aging was the topic we ultimately decided upon. The reason to choose aging was informed by the fact that high voltage XLPE cable technology is still quite young, and thus the aging process remains largely unexplored. Only in the coming years will the first HVDC cables begin to reach the end of their designed lifetime. Moreover, the understanding of insulation aging processes and associated behavior is an important part of ensuring the long-term stability of future cable installations.

The main concept that the research question was formulated around was to compare the performance of new and aged XLPE samples and to possibly develop a lifetime model through laboratory-aged samples. In the initial draft of the research question, the goal was to compare the insulating performance of three different artificial aging states: new-, medium-, and long-aged XLPE, from which a research question was then deduced. Thanks to the input of the other participants, some concerns regarding the specificity of the question were raised, prompting the group to improve upon this question. Since the summer school, several meetings have taken place, where future steps and final goals were discussed. At the moment, the main focus is on the literature review. Once complete, it will be possible to finally form a SMART research question. Unfortunately, this has not happened yet, as the research idea is still being fine-tuned. Most recently, there is a potential change of plan to not include artificially aged samples but use actual cable samples. In the process of finding a SMART research question, one attribute has proved to be the most challenging: attainability. Already, in the first rounds of discussion, there was the realization that the availability of instrumentation and other equipment would be the most limiting factor for this group. Thus, significant time is spent during the discussion, assessing the attainability of the proposal with the available equipment. Nevertheless, the willpower to finish this project is undeniably present, and the measurements are hoped to commence soon.

Group B—Yifei He, Naveen Janjanam, Philip Mathew, Maria-Irina Oancea, Yinka Leo Ogundiran, Timothy Wong, and Luming Zhou

Considering the HVDC theme of the summer school, this group decided to focus their efforts on novel strategies for increasing the ampacity of extruded XLPE HVDC land cables. Currently, a limiting factor to the power transmission capacity of cables is the thermal limit of the insulation. Resistive losses in the conductor core gradually cause the cable to heat up and, at elevated currents, could easily tend toward thermal failure, if left unchecked. Yet, increasing the ampacity of a cable could lead to economic benefits due to increased power density. Therefore, the idea was that any active (or passive) methods of improved thermal management should be able to increase the ampacity of a cable for the same conductor cross-section, see [5] for instance. We eventually settled on the research question "Can the addition of an intra-conductor embedded cooling channel in XLPE land cables increase the ampacity of the cable, and what are the effects of the fluid characteristics?" Although some studies have previously demonstrated the possibility of external fluid cooling [6], we would like to explore the effectiveness and feasibility of placing an active cooling channel inside the conductor core, as to not affect the properties of the existing insulating layers. This would further expand to investigate the effects of the fluid characteristics, such as flow velocity, inlet/outlet temperature, or viscosity.

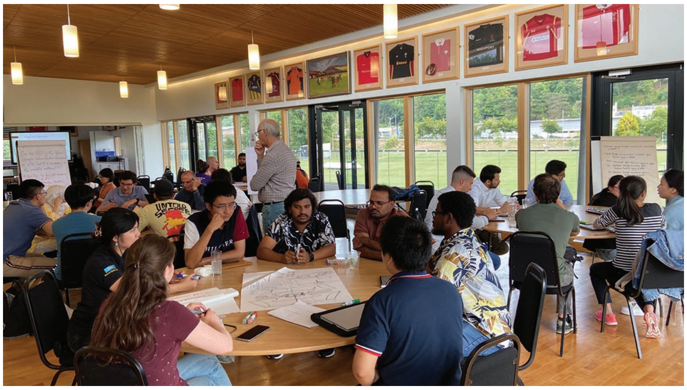

Figure 4. Participants working in groups to form different research proposals.

As multiple members of this group have prior experience with computational simulation, the novel concept would initially be tested in a series of multiphysics simulation studies. This would primarily focus on a performance comparison of the novel design to a traditional cable, while a secondary focus will be on the necessary considerations to terminate the cooling channel at the cable joints. The cable parameters could then be exported and integrated into a system-level model to evaluate its impact. If successful, future work may include the construction of an experimental prototype to test the concept in practice.

Group C—Faisal Aldaswari, Konstantinos Gektidis, Raj Hirani, Frances Hu, Fang Liu, Daniele Mariani, and Xiwen Wu

Group C included seven researchers with expertise in high voltage engineering, specifically partial discharge, space charge, material analysis, and other HV test techniques.

After understanding the need for HVDC applications and the sensitivity of HVDC insulating materials to temperature due to changes in conductivity, it was obvious that the thermal aging effects of materials such as EPDM and PP should be investigated, to predict the future aging characteristics of components. Hence, the group proposed "An Investigation into the Thermal Aging Effects on Electrical Properties of PP/EPDM for HVDC Cable Joint Applications."

Based on background information from previous literature, the group hypothesized the following.

1. Thermal aging increases mechanical weaknesses in EPDM, causing a decrease in PDIV according to IEC 60270.
2. After thermal aging, the level of accumulated space charges increases at the PP/EPDM interface.
3. DC breakdown strength increases after short-term thermal aging and decreases with longer aging periods.

The aim of the research proposal was to build a relationship model to predict electrical performance for HVDC cable joints. To do so, the group first proposed a literature review, to understand previous knowledge on aging, cable joints, sample preparation, and testing procedure. The thermal aging technique for the intended materials can then be optimized before testing is completed.

Samples will undergo chemical analysis, permittivity measurements, and partial discharge analysis, before and after aging. Also, DC conductivity and space charge measurements can be done. To investigate the performance properties, DC breakdown and lightning impulse testing will be implemented. The final goal—to build a relationship model between the electrical properties of PP and EPDM after thermal aging—can be completed after thorough data analysis.

The group has planned to expand and improve this research proposal after the summer school and work as a multinational team to develop an accurate and trustworthy model that is hoped to be used in future lifetime prediction models for cable accessories.

Group D—Giacomo Ciotti, Christian Mier Escurra, Jiachen Gao, Phichet Ketsamee, Patrik Ratheiser, Shahtaj, and Haonan Yang

The use of renewable energy has increased in recent years due to the energy transition. However, most of these renewable energy sources are located in rural, often remote, areas. This makes an efficient and climate-friendly energy transportation scheme an urgent necessity. HVDC transmission was proven to be a better solution for long distances than HVAC. Yet, some of the phenomena related to DC are not well known and are of great concern for utility companies.

One of the most important phenomena in this context is space charge accumulation. The presence of space charges may enhance the local electric field within the insulation material, and they are quantifiable with, e.g., the Field Enhancement Factor (FEF). However, a correlation between the FEF and the insulation breakdown voltage would be of major interest. This led group D to the following SMART research question: "What is a critical value for the FEF, related to the accumulation of space charges on XLPE, which leads to a breakdown in used insulation materials?" Hypotheses, such as "the DC breakdown voltage during a step test of the insulation material XLPE is inversely proportional to the field enhancement factor," were formulated. The common opinion regarding this topic is that space charge accumulation in XLPE leads to a breakdown in cable systems. Therefore, a lot of research has been conducted for XLPE with additives, which aim to reduce the space charge accumulation in the used insulation material. However, what amount of space charges would be considered critical in the insulation of DC cables? This further raises the question of whether this is necessary for every nominal DC voltage level. Additionally, the relation of FEF on the breakdown voltage should be investigated for DC XLPE cables (MVDC, HVDC, EHVDC). These points underline the relevance of the aforementioned matter.

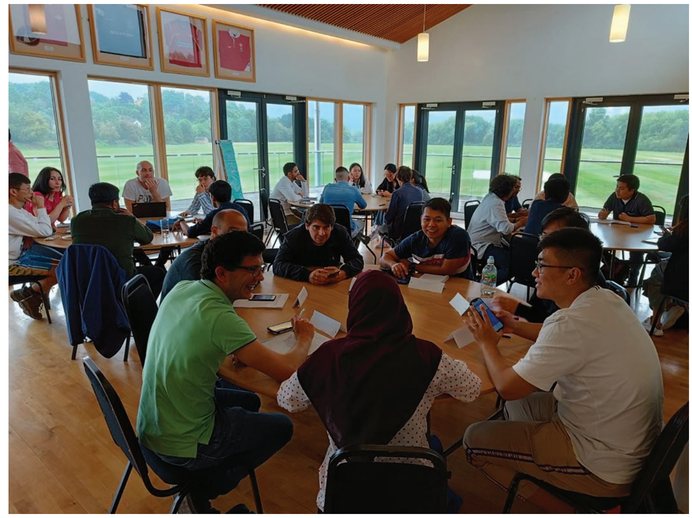

Figure 5. Group discussions.

During the considerations made by group D, the following specific objectives were defined. It is necessary to investigate the relation between space charges and breakdown voltage on plaque and cable samples at different temperatures. Furthermore, there is a need to characterize the investigated XLPE breakdown voltage related to the FEF, and a "critical" value for space charge accumulation for the investigated XLPE needs to be established.

Because the participants in this group have different skills and knowledge, we planned to divide the project into small work packages. The implementation should be done step by step, with each participant informing the others about their findings after finishing their work to achieve a smooth implementation. Because the project is very extensive and therefore requires many resources, approximately a year should be planned for it. As such, the best way to realize this project would be to either work as a group, internationally, with the support of the universities, or start a new PhD project. To implement this project in this form, financial and material resources need to be organized and obtained first.

Future Work

One thing that everyone has undoubtedly taken home is the newfound network of friends and colleagues. As most of us are in the early stage of our careers, we are very happy that the networking was kickstarted in the format of the IEEE DEIS Summer School. We not only extended our network, but also formed some crucial research collaborations. This is a perfect example of what happens when you put a number of young professionals in a room and give them something to discuss. In this sense, the summer school could be considered a kickoff meeting for multiple, international, research projects. We were all quite astonished that this was as successful as it was. We are all keen to see how these projects evolve over time and what publications might be spawned as a result of this year's summer school.

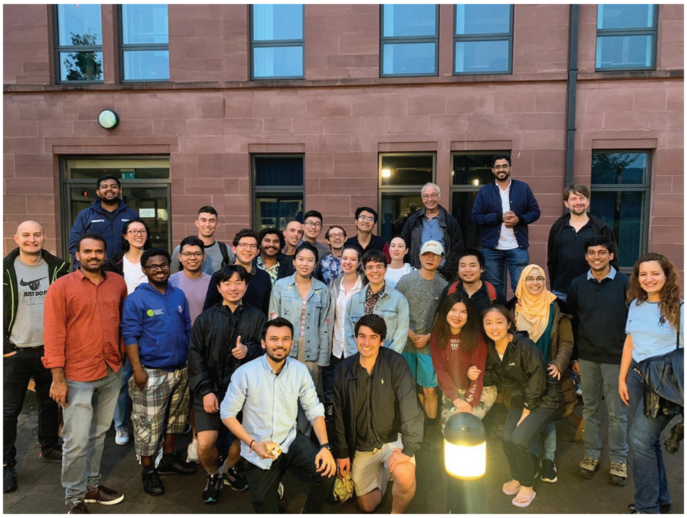

Figure 6. IEEE DEIS Summer School group photo.

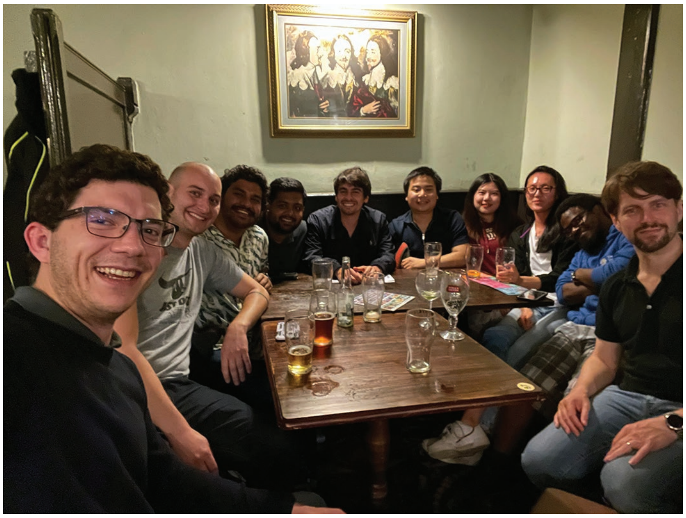

Figure 7. Participants enjoying the final night together before the end of the summer school.

The format of the summer school was perfect for young professionals. The group was not too big or too small. The circle of attendees provided the perfect environment to meet likeminded people. Also, the talks given were perfect to stimulate discussions, and there was enough room for ideas to be heard. We all sincerely hope that this will not be the last time the IEEE DEIS Summer School would be held—there is almost no better way for young professionals in this area to build up a network and start international research collaborations!

Fun Nights!

Apart from the scheduled presentations and discussions, an equally important (perhaps more important!) aspect of this summer school was the fun nights that we were able to spend together after daily sessions. Getting to know each other and developing a network with other participants in the same research field (and more importantly, at a similar career stage!) was incredibly beneficial to us. In the evenings, we stayed together, searching Monmouth for some good places to chat and drink. By spending several nights together, bonds were established between each and every participant, as well as to this summer school itself, by sharing our personal views and experiences beyond just research. Moreover, we are hugely grateful to the organizers for putting together the treasure hunt activity! This was held at the end of the summer school and aimed to encourage us to explore some famous sites around Monmouth and to familiarize ourselves with its history and culture, in the form of a competitive hunt for local landmarks.

Acknowledgments

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Fabian Bill, Frances Hu, Patrik Ratheiser, and Timothy Wong
Representatives of the IEEE DEIS Summer School class of 2022

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