Newsletter #6
February 2021

Focus on FASTGRID results

Welcome to the sixth and final newsletter of the FASTGRID H2020 project!

This issue aims to give you some of the main results of FASTGRID and interviews of some PhDs and our project manager.

FASTGRID started from a simple observation: the cost of the conductor for a Superconducting Fault Current Limiter (SFCL) was too high especially under high voltages. A SFCL is a smart device inserted in series for the line to be protected. Fully transparent in normal operations (very little voltage drop, no resistance (superconducting state), the SFCL intrinsically develops a high resistance (normal resistive state) as soon as the current oversteps a defined value which causes the loss of the superconducting state. The resistance limits very effectively the fault current. If the SFCL strongly limits the fault current, the latter must be cleared quickly (typically 50 ms). There is no non-superconducting FCL available at high voltages whereas the demand clearly exists, hence the strong interest of the SFCL but at reasonable cost. Figure 1 shows the Nexans SFCL installed in the medium voltage (10 kV) grid of the German city of ESSEN since spring 2014.


Nexans©

Figure 1: Nexans SFCL in a 10 kV substation of Essen (Germany) in operation since 2014.

FASTGRID reduced the cost by nearly one order of magnitude using three ways:

- the tape length reduction through the increase of the electric limitation field from typically 50 V/m (clearing time of 50 ms) to 130 V/m (same clearing time)
- the tape cost reduction through production with improved yield and higher critical currents (+ 100 %)
- the lowering of the liquid nitrogen bath temperature (77 K to 65 K) since the critical current is then doubled.

A complete techno-economic analysis from SuperGrid confirmed that the conductor cost dominates the total device cost, hence the strong interest of FASTGRID. For a 320 kV SFCL, the investment cost is reduced by a factor 4.4 using the FASTGRID conductor compared to a conventional one at 65 K.

The conductor is based on a REBCO THEVA Pro-Line tape bonded to a thick (500 µm) Hastelloy® shunt. The tape has made great progresses during FASTGRID: the critical current has been doubled and the dispersion of the critical current along the length has been reduced from 10 % to only 3 %. FASTGRID works have advanced beyond the state of the art for the REBCO tape elaboration at THEVA. ICMAB (Institut de Ciència de Materials de Barcelona) brought for example a better understanding of the oxygenation tape process, the new approach developed can be extended to all REBCO tape producers.

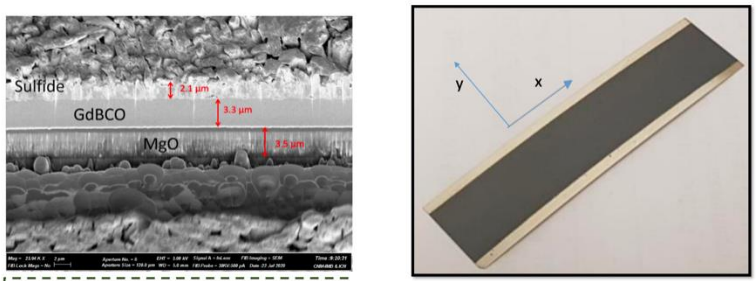
Extensive tests have been successfully carried out on short lengths of conductors but also on two pancake-shaped coils (figure 2) made by SuperGrid and tested at IPH (Institut Prüffeld für elektrische Hochleistungstechnik GmbH) in Berlin. These coils are the basic elements of an industrial device.

Figure 2: One pancake-shaped coil tested at IPH in Berlin.

A thorough and unique Life Cycle Analysis (LCA) was carried out by the partner KIT on the THEVA Pro-Line and OXO (OXOLUTIA) tapes. This LCA has quantified the large environmental advantage of a SC conductor compared to a copper one for most categories, especially acidification (20 %), freshwater ecotoxicity and eutrophication (30 %), marine eutrophication (25 %), particulate matter (20 %), photochemical ozone formation (30 %) …

But FASTGRID is not only this clear leap forward in the REBCO conductor for SFCL.

REBCO tapes suffer from a low normal zone propagation velocity (NZPV) with unfavourable consequences for most SC applications. EPM (Ecole Polytechnique de Montréal), a partner of FASTGRID, has patented a mean to increase the NZPV significantly by introducing the Current Flow Diverter in the tape architecture. ICMAB has successfully implemented the CFD (figure 3) using a simple and versatile way (Ag sulfide). The measured NZPV is increased by one order of magnitude in agreement with the numerical simulations. This result is very important since it enhances the security of operation for most HTS applications.



ICMAB©

Figure 3. Silver Sulfide Current Flow Diverter tape.

Another breakthrough in the protection of HTS applications is the implementation by the partner EPFL of a new patented system to detect “hot spots” using optical fiber. These “hot spots” are local defects often leading to damages of the application since they are very difficult to detect. The advantages of this innovating detection tool are its quick detection time within 10 ms, its low cost and simple implementation (see Newsletter 5). Like for the CFD, the exploitation of this result may be very important.

FASTGRID explored two alternative ways for the conductor with attractive potentialities for SFCL.

The first way is REBCO tapes based on a sapphire substrate. These breakthrough tapes for SFCL were proposed by TAU (Tel Aviv University). FASTGRID aimed to develop this high potential route and increase its TRL. These tapes indeed show electrical fields under limitation up to 2000 V/m to be compared to 50 V/m for conventional conductors. TAU, ICMAB and OXO made within FASTGRID advances both from theoretical and elaboration points of view on this game changing tape in the SFCL technology. Several phenomena are much better understood. One outcome of FASTGRID is the successful elaboration of 1 m long sample (figure 4). The next challenge is the reel-to-reel manufacturing but FASTGRID paved the way in this direction.

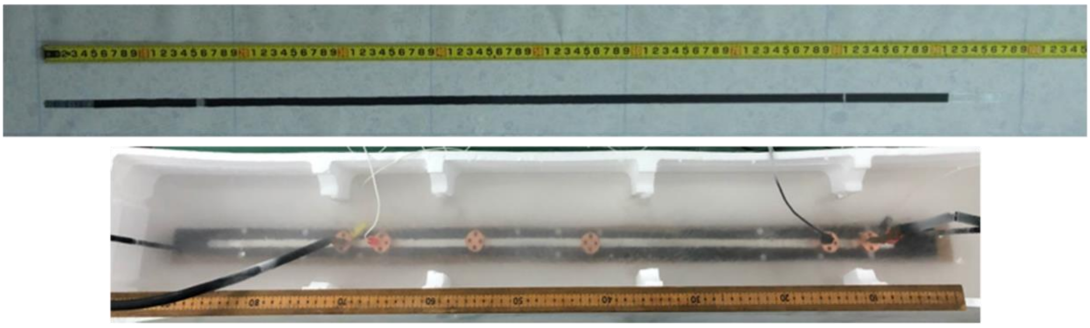
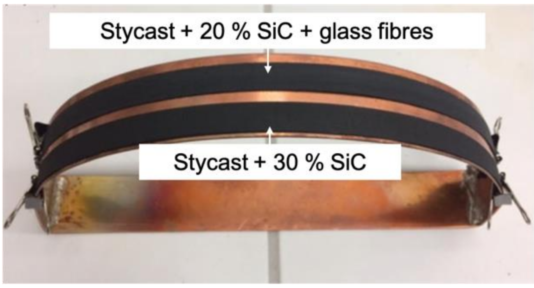

TAU©

Figure 4. 1 m long REBCO tape based on a sapphire substrate.

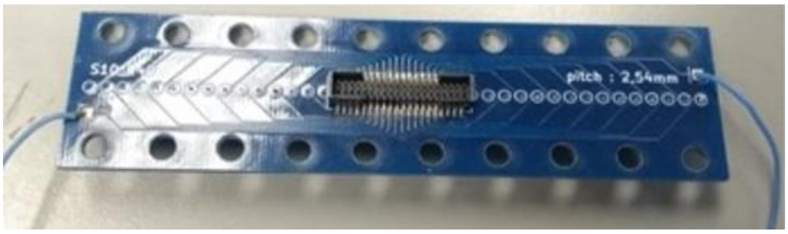
The second way investigated by FASTGRID is a new conductor called high cp (specific heat) shunt developed by IEE (Institute of Electrical Engineering) and STUBA (Slovak University of Technology in Bratislava). It brings an attractive option for SFCL conductors. This high cp shunt is made of epoxy resin combined with ceramic fillers (Al_2O_3, SiC, glass fibers, figure 5) to fit the thermal expansion of the tape. Reduction of the maximum temperature reached during limitation process has been confirmed experimentally. FASTGRID has demonstrated the possibilities of this emerging solution. As for the sapphire based tape, the next challenge is the reel-to-reel manufacturing.



STUBA©

Figure 5. High cp conductor.

The experimental tests, characterizations and simulation works have been a continuous support to the project results and they have progressed during FASTGRID in the different partners involved (CNRS, KIT, RSE (Ricerca Sistema Energetico), EPM, IEE, SuperGrid). Figure 6 shows for example an innovating multi-voltage tap sample holder developed by EPM. This sample holder makes possible to record up to 80 voltage distributed on the surface of the sample (tape).



EPM©

Figure 6. Innovating multi-voltage tap sample holder.

SuperGrid and RSE have developed test procedures for HVDC SCFL which could become future standards. Writing standards always brings a strong impact to the authors.

In short, FASTGRID made possible a leap forward in the performances and cost of SFCL besides the numerous advances about CFD implementation, quench detection, sapphire substrate tapes, high cp shunt, simulation and experimental tools, etc. All the more there is a clear and real demand today for SFCL. Many transdisciplinary works and great collaborations between partners were carried out. Most of these advances are valid for other SC applications so the exploitation of FASTGRID goes beyond SFCL. The works do not stop with the end of FASTGRID. Many of us, companies inter alia, are convinced about the interest of the developments that will be pursued. FASTGRID was a fantastic and essential trigger.

I am proud to have coordinated FASTGRID and its results. I thank the 11 partners and Europe for their trust and for the rich exchanges throughout the project. One of my regrets is the absence of a final face-to-face meeting, but we will have the opportunity to meet to discuss this great scientific adventure.

Pascal Tixador

FASTGRID coordinator

Interviews of FASTGRID young professionals

This last newsletter is the opportunity for us to share the portrait of 4 young professionals involved in the FASTGRID project.

Arooj Akbar, PhD student at EPFL

"I started my PhD in the Applied Superconductivity Group at EPFL, Switzerland in February 2019. At that time I was a newcomer in both the superconductivity community and in the FASTGRID team, as the project was already in full swing. Starting in a new field and joining a project in the middle of its activities was slightly overwhelming but I felt right at home within the friendly and dynamic FASTGRID team.

Throughout the project, I had the pleasure of attending the project meetings and got the opportunity to interact with and learn from a truly international and vibrant community.

Within the course of the project, I worked on and patented an innovative technique for fast hotspot detection in superconductors using optical fiber sensing. I got hands-on, and had the exciting occasion to experiment at Supergrid Institute, Lyon, and test the hotspot detection technique on the FASTGRID pancake. FASTGRID, for me was an experience that amalgamated learning, networking and professional growth. I am happy to have been part of such a stimulating experience."

Alexandre Zampa, PhD student at CNRS

"I started my PhD with CNRS in Grenoble in October 2018, more than a year and a half after the kick-off of the FASTGRID project. I was directly involved in the experimental characterization on small lengths of the FASTGRID conductor. This task is particularly important as a first step in the validation process. Be part of this project also gave me the opportunity to better understand the limitation phenomenon in 2G HTS coated conductor, combining modelling and experimentation to better perceive how the current is distributed when a quench occurs. I have the feeling to contribute to the common knowledge about these tapes.

FASTGRID was my first experience with so many partners from different fields of science and technology. This was my favourite aspect of the project. Indeed, it makes possible to develop new ideas with other partners and to work on common issues. I had the opportunity to learn a lot about modelling superconducting tape thanks to the help of our colleagues from EPM during a stay in Montreal. Also, with Pedro Barusco, PhD student at ICMAB, we are working together on the development of new architectures of superconducting conductor to reach high electric field!

This project was also my first encounter with superconductivity. It was quite challenging to deal with a completely new topic. I highly appreciate it due to the specific position of superconductivity at the interface of several fields as electrical engineering, thermal and mechanical problems for example.

Being a PhD student in FASTGRID meant to discover many professions as being an actor! With my colleague from CNRS, Julie Djebrani, we were the main characters of the FASTGRID video. I enjoyed it a lot but I definitely prefer Research to cinema!

A particular thought goes to partners I worked with and contribute to help me to professionally progress".

Julie Djebrani, European Project Manager at CNRS

"I started working as the Project Manager of FASTGRID in October 2018. I had to adapt to my new position very quickly as the project was well underway at that time.

A few weeks after my arrival, we all flew to Bratislava, Slovakia for the 5th Project Meeting and I finally met all the consortium members physically. I have no scientific background and I was very impressed to see all these passionate researchers sharing their results, examining curves from every angle…

One of the most memorable moments for me was the shooting of the FASTGRID video with my colleague Alexandre Zampa. It was strange, but also very funny to wear a lab coat and pretend to be an expert in superconductivity!

Now that FASTGRID has just ended, I can tell that managing all administrative and financial aspects of a European project was not always easy, but it was a great experience!

I am very glad to have supported this hard-working scientific community."

Alexander Buchholz, PhD student at KIT

"I started my PhD at the Karlsruhe Institute of Technology, Germany in summer 2018 when FASTGRID had already started. As an environmental scientist, it was the first time I got in contact with superconductivity, so it took some time to getting used to the topic. However, the entire FASTGRID team was incredibly friendly and helpful, no matter how trivial my questions may have been to an expert.

My task was to conduct a life cycle assessment of high-temperature superconductor tape production, which was challenging but also very intriguing. This task was important because environmentally friendly production is becoming increasingly important in today's world. While my work always seemed to be a little exotic within FASTGRID, I really felt like my work was valuable and appreciated by the other project partners.

FASTGRID was my first project, but I got a lot of great memories and experiences from it. In addition to the various project meetings where I was able to get to know the work of my colleagues, my visits at THEVA were also a special feature of this project. It is a rare opportunity for an LCA practitioner to be allowed to look at production processes in such detail.

I would like to thank the whole FASTGRID team for the cooperation and I am really glad that I was part of this project."

FASTGRID Project Meetings

The FASTGRID project started in January 2017. Since then, 8 project meetings were organized in 6 different countries.

These friendly events were the opportunity for the consortium members to share their results, work in parallel sessions and visit the facilities of the hosting institution.

It is a pity the final meeting could not take place in Grenoble as planned from the beginning of the project. The health situation prevented us from gathering physically one last time, but we will surely meet again in the future!

FASTGRID consortium

Centre National de la Recherche Scientifique

SuperGrid Institute

Institut de Ciència de Materials de Barcelona

Theva Dünnschichttechnik GmbH

Ricerca sul Sistema Energetico - RSE S.p.A.

Ecole Polytechnique de Montréal

Tel Aviv University

Karlsruher Institut für Technologie

Institute of Electrical Engineering, SAS

Ecole Polytechnique Fédérale de Lausanne

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