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TESTINGLY

Testing, Inspection & Certification Magazine

Real challenges
for eco friendly
power networks

magazine by

KEMA Labs

Testingly

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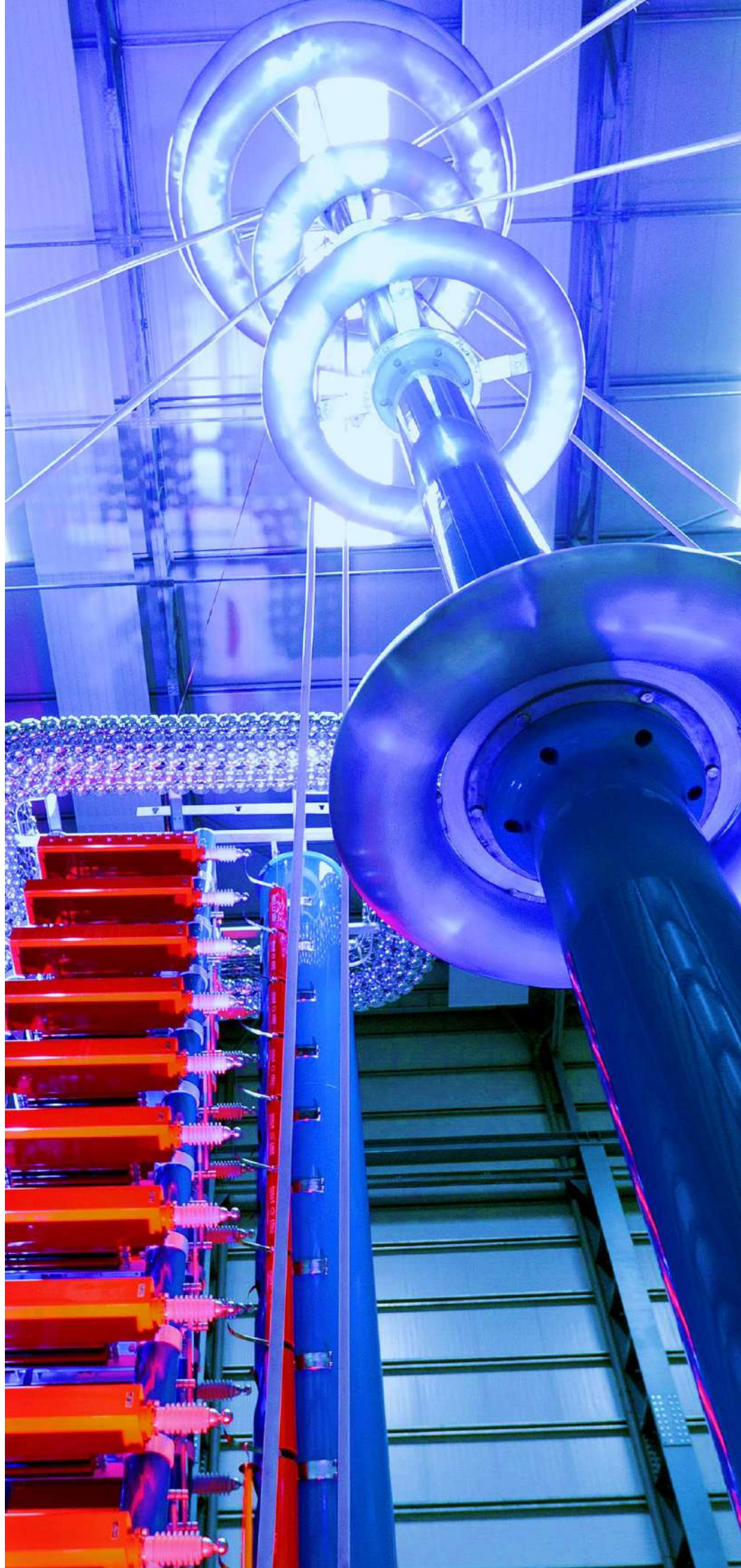
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“

We believe and practice the importance of minimizing the impacts of testing activities on the planet

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Matteo Codazzi
CESI Group CEO

Decarbonizing power grids: Solutions from TSOs and utilities

With the economic effects of the pandemic and the war in Ukraine, it is extremely complex to analyze and make exact projections about future energy scenarios. Though, one thing can be said with certainty: the war and its effects on the energy markets will cause severe repercussions on the prospects of global economy. Let us pause here to recognize and reflect on those who are currently suffering as a result of the war being waged in the Ukrainian territory. We wish for peace to be restored soon.

Even in light of the ongoing conflicts around us, we cannot postpone the **decarbonization process**, especially in regard to **power grids**. In support of this, on March 17th we hosted a webinar: *The real challenges in transition to eco-friendly power networks*. An event in which **key experts from Transmission Operators and Components and Systems Manufacturers** explained their role and advancements in developing environmentally friendly power networks for building a **sustainable future**.

The webinar originated from our **commitment to the protect the global environment**. Not only do we believe and practice the importance of minimizing the impacts of testing activities on the planet, but there are also mandatory legislation or regulations that support this. We brought together the **most knowledgeable stakeholders** to share viewpoints on how to get to a **more ecofriendly transmission network** and the technology required to get there.

In this respect, this issue of **Testingly**, the KEMA Labs magazine, opens with a summary of the event that took place on March 17th. In this recap, you will find the main technologies, solutions, and proposals we discussed in the webinar, as they were told by the renowned speakers who took part in the two roundtables.



“

Our sector has big challenges ahead when it comes to the decarbonization of each power network component

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*Domenico Villani – KEMA Labs,
Executive Vice President*

Due to their important role in decarbonizing the grid, for we have interviewed **Akshaya Prabakar** (Corporate Social Responsibility Program Manager at **TenneT**), **Mark Wilkinson** (CTO of **Royal SMIT Transformers**) and **Mark Waldron** (Net Zero Asset Strategy Technical Leader at **National Grid**). The three experts, who also took part to our webinar as key speakers, assessed important topics such as SF6-free alternatives, transformers, and ecofriendly transmission networks.

In addition, in the *Innovative Technologies* section, we explore several solutions aimed at making **transformers** more environmentally sustainable, by reducing losses and promoting more environmentally friendly insulation and cooling fluids, while also improving their correct functioning.

Our *Decarbonization Strategy* section is focused on **SF6-free alternatives**, featuring an in-depth article analyzing solutions for the **decarbonization of switchgears** (through alternative gases) and scalable high voltage switchgears.

Our sector has big challenges ahead when it comes to the decarbonization of each power network component. We hope that our webinar and the present issue of *Testingly* will provide you with a comprehensive overview on the latest developments and future initiatives.

We are sure you will enjoy the read.

Matteo Codazzi – CESI Group CEO

Domenico Villani – Executive Vice President CESI TIC Division – KEMA Labs

Latest news from the TIC industry



KEMA Labs latest on-site tests on cable systems

In the period 29 March to 5 April 2022 KEMA Labs, Arnhem in cooperation with KEMA Labs, Berlin, have successfully performed on-site tests on two 220 kV, 10 km long, cable systems from LS Cables & Systems, for Landsnet in Akureyri, Iceland.

The new cable systems will first be operated at 132 kV but are ready to become part of the future 220 kV grid in Iceland. The SAT consisted of an over sheath voltage test, HV AC test at 216 kV, a PD test at 170 kV, cross-bonding verification, impedance, and TDR measurements.

For the HV test two test trailers were needed to reach the required test parameters of 216 kV and 113 A. During all tests no breakdowns occurred, no PD was detected, and no abnormalities were observed.

Test on an air-core neutral grounding reactor



In February 2022 KEMA Labs, Prague, Czech Republic, have successfully performed a test on an air-core neutral grounding reactor with an inductance greater than 100 mH for the customer Coil Innovation GmbH, from Austria. Neutral Grounding Reactors are single phase reactors generally connected between ground and neutral of transformers or generators in order to control single line-to-ground faults at a desired level.

Due to the large inductance of the reactor, the test was very interesting from a technical point of view because the drop voltage on the reactor reached a value well over 100 kV, so the test circuit had to be properly designed not only in terms of current when in case of failure the current from generators could reach up to 140 kA, but also in terms of voltage. 10 dynamic short circuits were applied to the reactor, which is far more than requested by the IEC, and then the reactor was subjected to a thermal short circuit current 3,15 kA for 2 s. After each test, a detailed inspection was successfully performed on the reactor.



New versions of the EN-IEC product standards for electricity metering equipment

In June 2020 new versions of the EN-IEC product standards for electricity metering equipment, namely IEC 62052-11, IEC 62053-21, -22, -23, and -24, were published.

These second editions cancelled and replaced the first ones published in 2003, and their amendments in 2016. The 2020 versions mentioned that the IEC technical committee TC13 recommended the adoption for implementation not earlier than two years from the date of publication.

National legalization bodies, utilities and manufacturers are now expected to adapt to these new product standards during 2022.

The KEMA Laboratories are ready to test, having developed their own facilities and implemented the required procedures and methods.

JOIN US

The real challenges in transition to eco-friendly power networks

European TSOs and global manufactures discuss real energy transition challenges

Webinar - March 17th 2022,
10.00 am - 12.30 pm (CET)

Organized by
KEMA Labs
a CESI Division

You can watch the event at this link: <https://www.cesi.it/webinars/the-real-challenges-in-transition-to-eco->

ECO-FRIENDLY POWER NETWORKS

How are utilities and technologies evolving?

Transitioning to **ecofriendly power networks** represents both a challenge and an opportunity for the energy sector.

Utilities and manufacturers play a crucial role in implementing environmentally friendly power networks for building a **sustainable future**, setting the milestones to achieve **ecofriendly transformers and switchgear**, and promoting the transition to greener alternatives for **sustainable power transmission**.

In this respect, on March 17th, 2022, KEMA Labs had launched the event *The real challenges in transition to eco-friendly power networks*, which hosted **key experts from Transmission Operators and components and systems Manufacturers** to discuss the above-mentioned topics.

The KEMA Labs event was comprised of **two roundtables** in which representatives of Transmission Operators and Manufacturers, respectively, assessed the current situation and discuss about the future landscape.

During the first roundtable – *How are the utilities gearing up for making the transition to eco-friendly networks?* – the key speakers were **Sener Olaf** (Director of Asset Management – **TransnetBW GmbH**), **Maria Rosaria Guarniere** (Realization of plants and technologies Manager – **Terna**) and **Andrea Valant** (Head of Substation Technology Development – **Terna**), **Akshaya Prabakar** (Corporate Social Responsibility Program Manager – **TenneT**), **Aurelien Taureau** (Chef De Pole – **RTE** – Pôle Gestion de l'Infrastructure) and **Mark Waldron** (Technical Leader – Nationalgrid).



The second roundtable, titled *How are the product technologies evolving for soon to be built eco-friendly power networks?*, has featured **Christian Ohler** (Head of Portfolio Management, High Voltage Products – **Hitachi Energy**), **Mark Kuschel** (CTO Switching Products & Systems – **Siemens Energy**), **Bertrand Portal** (Senior Product Manager – **GE Renewable Energy**), Jin Ho Kim (Vice President, Head of ChangWon Plants – **Hyosung Heavy Industries Changwon Plant**) and **Mark Wilkinson** (CTO – **Royal SMIT Transformers B.V.**).

Furthermore, the webinar was concluded by Norela Constantinescu (Head of Section Innovation at **ENTSO-E**) who spoke about the solutions proposed by ENTSO-E to enhance grid use and the development for a **pan EU market**. Mrs. Constantinescu addressed, in particular, the roadmap to **reduce SF6 emissions in both existing and new HV equipment** and the common technical specifications for performance and the testing of alternative SF6-free technologies. She, also, spoke about the ENTSO-E members goal to reduce CO2 equivalent emissions along **TSO value chain** through planning, asset management and decommissioning phases. Finally, the Head of Section Innovation at ENTSO-E pointed to new technologies enabling system development to substitute the lead in **HVAC and HVDC cables**.

Before Norela Constantinescu's final remarks, during the first roundtable, the main topics assessed included the role of the power sector as the main driver of **sector integration**, **Natural Ester Filled Transformers**, integrating **renewables into the grid** without causing power losses, eliminating the reliance on **SF6** in measurement and power transformers, and **SF6-free Technology and Utility Risk Management**.

In this respect, Sener Olaf (TransnetBW) pointed out that "Due to its outstanding **decarbonization** opportunities, the **power sector is the main driver of sector integration** and, by 2050, wind and photovoltaic will be the main sources for the power generation, thus demand flexibility will play a huge role in 2050: other than today, in 2050 the availability of RES will define load peaks." According to Andrea Valant and Maria Rosa Guarniere of Terna, Natural Ester Filled **Transformers** and **NZEB HV Electrical Substation Buildings** will play a crucial role in the future ecofriendly power networks: "The aim is to define, from a design, architectural and functional point of view, **Substation Buildings at «nearly zero energy»**. The goal was achieved through the study of appropriate interventions to be implemented on the building envelope together with the adoption of smart technological systems, in addition to the use of supplementary power solutions from solar renewable sources. The design solutions have been defined for both existing and new buildings and have successfully been realized."



In addition, Akshaya Prabakar from TenneT explained that “**TSOs** are in a unique role to **accelerate the energy transition** and at the same time be conscious about how it is being done. One such example would be that the energy transition comes with a huge project portfolio and will see a tremendous increase in renewable energy being connected to the grid, which would in turn mean large transporting distances and therefore more grid losses, which are the predominant source of emissions in the TSO sector.” In addition, the TenneT expert said the TSO is aiming to have **2/3 of SF6-free new assets by 2030**.

Aurelien Taureau (RTE) and Mark Waldron (Nationalgrid) focused their presentations on **SF6-free alternatives**. According to Mr. Taureau, the solutions include “No longer use of SF6 in measurement and power transformers, when available, use of GIS SF6 alternatives and support to manufacturer initiatives, such as the EU LIFE projects.” Nationalgrid, according to Mr. Waldron, supports “National and regional penalties for SF6 emissions, moving towards SF6 bans, specific, binding emission reduction targets, development of SF6-free solutions, industry engagement to ensure solutions are realistic, deliverable and timely, and a legislation directly linked to societal willingness-to-pay, in order to keep all stakeholders engaged to ensure plans are proportionate and supported.”

In the second roundtable, components and systems Manufacturers discussed, for instance, about SF6 from their point of view. Christian Ohler (Hitachi Energy), for instance, presented an **eco-gas mixture** that “is always used as a mixture, it essentially eliminates CO2 equivalent emissions related to the insulation gas and delivers the lowest CO2 footprint of the equipment.” GE Renewable Energy, according to Bertrand Portal, claimed that the main pillars enabling the **g3 technology adoption** and accelerating power network decarbonization are “regulatory support, the role of switchgear manufacturers and users.”

Mark Kuschel (Siemens Energy) stated that “**clean air for F-gas-free grids** is already a reality today,” as he pointed to the benefits of clean air and **vacuum switching** in terms of cutting emissions. Jin Ho Kim (Hyosung Heavy Industries) offered a different perspective, as he focused on the “Korea market trend of **ecofriendly GIS**,” underlying the “development status of domestic manufacturers for ECO 170kV 50kA GIS.” Finally, Mark Wilkinson (Royal SMIT Transformers B.V.) highlighted the challenges for **transformer OEM’s**, assessing the entire life cycle of the transformer.

The entire webinar as well as the presentations of all the speakers are available, for free, at this [link](#).

Akshaya Prabakar

TENNET



Akshaya Prabakar

Corporate Social Responsibility Program Manager at **TenneT**

- Challenges for TSOs
- Market innovations
- Reducing TenneT carbon footprint



Akshaya Prabakar is Corporate Social Responsibility Program Manager at **TenneT**. She is Responsible for Climate, Nature and Human Rights for TenneT NL and Germany. She has a background in electrical engineering and have been with TenneT for three years.

Hello Mrs. Prabakar. Could you please briefly describe yourself and your role at TenneT?

I am Akshaya Prabakar and work as a corporate social responsibility program manager at TenneT. My responsibilities include the themes of climate, nature and human rights and I develop policies and targets that drive TenneT to lead as a green grid operator while accelerating the energy transition. Having a background in electrical power engineering certainly helps me in understanding the intricacies of the role of being a cross border transmission system operator while challenging ourselves to be a socially responsible organization.

What are some of the key challenges that TenneT and TSOs are facing today with respect to ecofriendly power networks?

TSO's are in a unique role to accelerate the energy transition and at the same time be conscious about how it is being done. One such example would be that the energy transition comes with a huge project portfolio and will see a tremendous increase in renewable energy being connected to the grid, which would in turn mean large transporting distances and therefore more grid losses, which are the predominant source of emissions in the TSO sector. The challenge here is to find a balance between these two sides. At every integral decision making, it is important to consider affordability, reliability and sustainability as factors when addressing the topic of ecofriendly power networks.

How is TenneT trying to overcome such challenges?

Our approach in general is three-fold. We try to reduce our emissions as much as possible, and then green the parts of our emissions where applicable and lastly, compensate for the parts which we absolutely cannot avoid due to other technical factors. We also stimulate market innovations and collaborate with our suppliers and contractors to work together towards finding solutions for these challenges. We steer on our sustainability performance and often are involved in open dialogues with the business units on reducing our impact on the planet.

What are the steps in action to reduce your footprint?

We actively steer across our corporate social responsibility ambition which includes the themes of people, planet and profit. We are proud to have recently committed to the science based targets initiative with a commitment of 95% absolute reduction in our scope 1 and 2 emissions by 2030 and a 30% absolute reduction in our scope 3 emissions by 2030 when compared to a 2019 baseline. Here are a few examples of how we are taking actions in reducing our footprint along the three scopes as standardized in the greenhouse gas protocol. For scope 1, we have ambitious targets on reducing our banked SF6 volume by choosing for SF6 free alternatives where available and limiting the leakage rate to a minimum. For scope 2, we buy guarantees of origin to green our grid losses in the Netherlands thereby reducing our net carbon footprint and for scope 3, we are working with our supply chain partners and stimulate them to come up with innovations to reduce our indirect emissions. In 2021, we greened 69% of our carbon footprint. More details on the different steps we take to reduce our footprint can be found in our integrated [annual report](#).



Mark Wilkinson

ROYAL SMIT TRANSFORMERS



Mark Wilkinson

CTO of Royal SMIT Transformers

- Power transformers and compensating reactors
- Re-cycled materials
- CO2 reduction in transformers



Mark Wilkinson is the CTO of **Royal SMIT Transformers** in Nijmegen, The Netherlands. He is responsible for Innovation and R&D, and future technology direction for large power. Based in Nijmegen since 2008, his previous roles within SMIT have included Engineering Manager, Technical Director and COO.

Hello Mr. Wilkinson. Could you please briefly describe yourself and your role in Royal SMIT Transformers?

Hello, I am currently the CTO of Royal SMIT Transformers in Nijmegen, the Netherlands, with responsibilities of R&D and Innovation for Large Power Transformers. My role within SMIT is to ensure we are 'Fit for Future' in terms of materials, processes, and products. Our core business is the design and manufacture of large power transformers and compensating reactors, mainly in the range of 100 MVA to 1000 MVA and 150 kV to 765 kV.

What are some of the key challenges that transformer original equipment manufacturers are facing today?

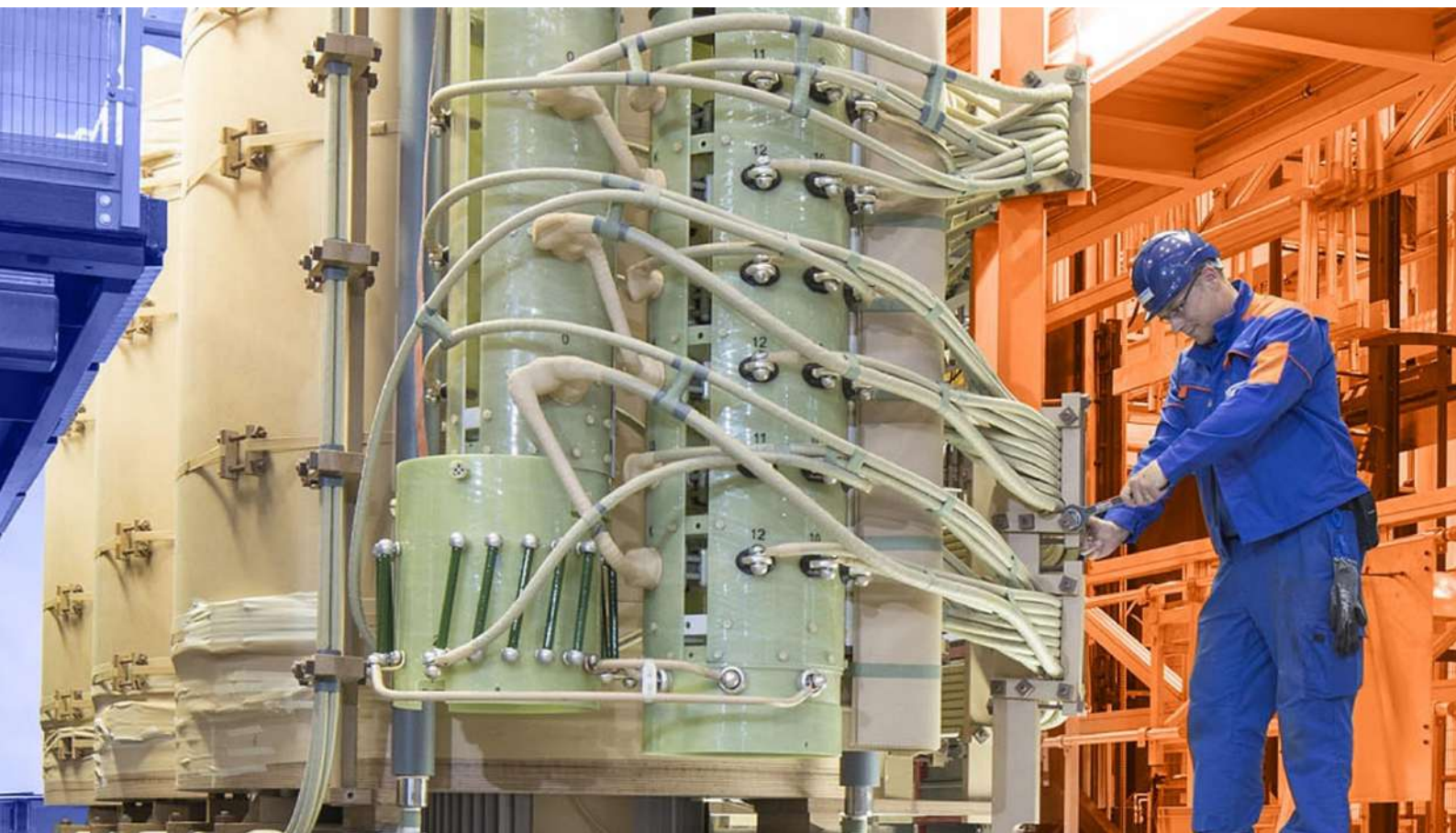
The key challenges at the moment revolve around finding suitable manpower resources and sufficient material availability. The supply chain is still recovering from the effects of the Covid pandemic, and now the tragic war in Ukraine is causing further disruption. Material availability is currently unpredictable, and material pricing is extremely volatile. For a product that may have an order to delivery time of up to 24 months, this combination poses particular difficulties for us.

How are you trying to overcome such challenges?

On the manpower front, we keep in close contact with the technical universities and colleges, for example by sponsoring final year projects. For the material demand, it is important that we keep as close as possible to our customer, so we can anticipate their demands. The final destination of our products is traditionally split equally between the USA And Europe, and each market has its own characteristics. For our suppliers, we are developing a wider base of suppliers for key components, and providing longer term forecasts, to ensure timely delivery of parts.

What is Royal SMIT Transformers currently doing to cut greenhouse gas potential for transformers? And what are the long-term plans and goals?

Firstly, we are checking where are the largest contributors to the greenhouse gases are in our products (we say '*meten is weten*' in Dutch, which means 'measuring is knowing'). We are looking to use more re-cycled materials, for example 40% of our Copper is now re-cycled. For grain orientated electrical steel, we have started a cooperation with Thyssenkrup Electrical Steels to use Bluemint® steel, which has 50% less CO₂ intensity during production. Longer term, our aims are to reduce all non-recyclable waste by 25% before 2025, and to reduce our CO₂ equivalent/MVA by 50% before 2025.



Mark Waldron

NATIONAL GRID



Mark Waldron

Net Zero Asset Strategy Technical Leader at **National Grid**


- SF6-free technology
- TSOs main challenges
- Net-zero targets



Mark Waldron has more than 30 years' experience in the field of switchgear and substation equipment in a transmission utility environment. His present role in **National Grid** is Net Zero Asset Strategy Technical Leader, with a particular focus upon SF6 management and SF6 alternatives in the context of National Grid's wider responsible business commitments and ambitions, and the role of electricity transmission in facilitating the future energy system.

Hello Mr. Waldron. Could you please briefly describe yourself and your role at National Grid?

I'm an electrical engineer with over 30 years' transmission utility experience of high voltage substation equipment, particularly switchgear. As Technical Leader for Net Zero Asset Strategy within National Grid Electricity Transmission I focus on the strategic roadmap for our transmission system assets, and how these assets contribute to our environmental commitments and ambitions. A key focus is responsible management of SF6 and technology solutions that can eliminate SF6 inventory and emissions.



What are some of the key challenges that TSOs are facing today with respect to ecofriendly power networks?

Our macro challenges include connecting increasing amounts of renewable energy, managing the environmental impact of our network, and supporting long-term decarbonization goals e.g. heat and transport. Our environmental action plan addresses topics including net-zero carbon emissions, minimization of waste, sustainable use of materials and care for the natural environment. Focusing on carbon emissions, SF6 emission is the biggest contributor to climate change under our direct control and is a key focus area for us.

How are Nationalgrid trying to overcome such challenges?

Our SF6 commitment is to reduce emissions by 50% by 2030 from 2019 levels and we have set an ambition to eliminate SF6 from our assets by 2050. We have a policy not to use SF6 where alternatives are available. Best practice management of SF6 and progressive replacement of SF6 inventory require a portfolio of techniques; prevention, repair, refurbishment, conversion (retro-fill) and replacement. SF6-free technology for conversion & replacement is becoming commercially available. A range of solutions now exist for our 132kV network but a full portfolio of 400kV options is still in development and we work closely with suppliers to accelerate development.

Generally speaking, what are your strategy to reduce the carbon footprint?

By utility standards technology is moving rapidly and questions remain around technology diversity, long-term asset performance and ownership, and future developments in EHS legislation. We must meet our net zero targets, but we must do so by taking a holistic, societal view of the role of electricity networks, accounting for the needs of all stakeholders, and using robust life cycle and carbon assessment techniques. For example, global warming potential of gases is a critical parameter, but not the only one!



Installation of Transformer T401, built by Siemens Energy, at KEMA Labs in Mannheim (Germany)

INNOVATIVE TECHNOLOGIES

Power Transformers go green

The huge development and progress in the transmission and distribution of electrical energy during the past 130 years was made possible by the **power transformer**. Such critical component is capable of efficient and reliable linking generation via transmission and distribution to the loads, at each stage operating at its most suitable voltage.

This unique ability of the transformer to **adapt the voltage** to the individual requirements of different parts of the power system is derived from the simple fact that it is possible to magnetically couple the primary and secondary windings of the transformer.

The coupling of the windings is done in such a way that their turns ratio will determine very closely their voltage ratio as well as the inverse of their current ratio.

The output and input volt-amperes and the output and input energies being approximately equal. The efficiencies range from **99% for distribution transformers** to **99.7% for large grid transformers**.

Transformer design and manufacturing is a complex process considering dielectric, electromagnetic, thermal, mechanical, and environmental aspects, many of which are interrelated.

In order to better understand the challenges for power transformers, the bigger picture is needed. Firstly, the developments of the electrical power system. In large parts of the world the grid and its equipment, including transformers, is old, calling for replacement based on grid owner and operator's asset management tools supported with measurements and diagnostics.

“ *Due to the **sustainable energy transition and increasing electrification** a rapid expansion of the grid is needed, as the share of electricity in the energy mix is expected to more than double in the year 2050.* ”

This rapid electricity growth calls for standardization to be able to build more and faster, **flexible solutions** to temporary solve bottlenecks, increased loading of the grid and relaxing of the (famous) N-1 reliability criterion for the higher voltage levels stating that always one component can fail without power delivery interruption, even during maintenance.

For power transformers, this implies that, for example, increased plug-and-play provisions like **plug-in-bushings and cable connectors** are employed and even temporary (mobile) transformer substations are asked for mitigation of bottlenecks in the grid.

Mobile solutions could play a role to reduce the planned outage of (parts of) existing substations during maintenance and refurbishment, and thus increase reliability and even resilience of the grid.

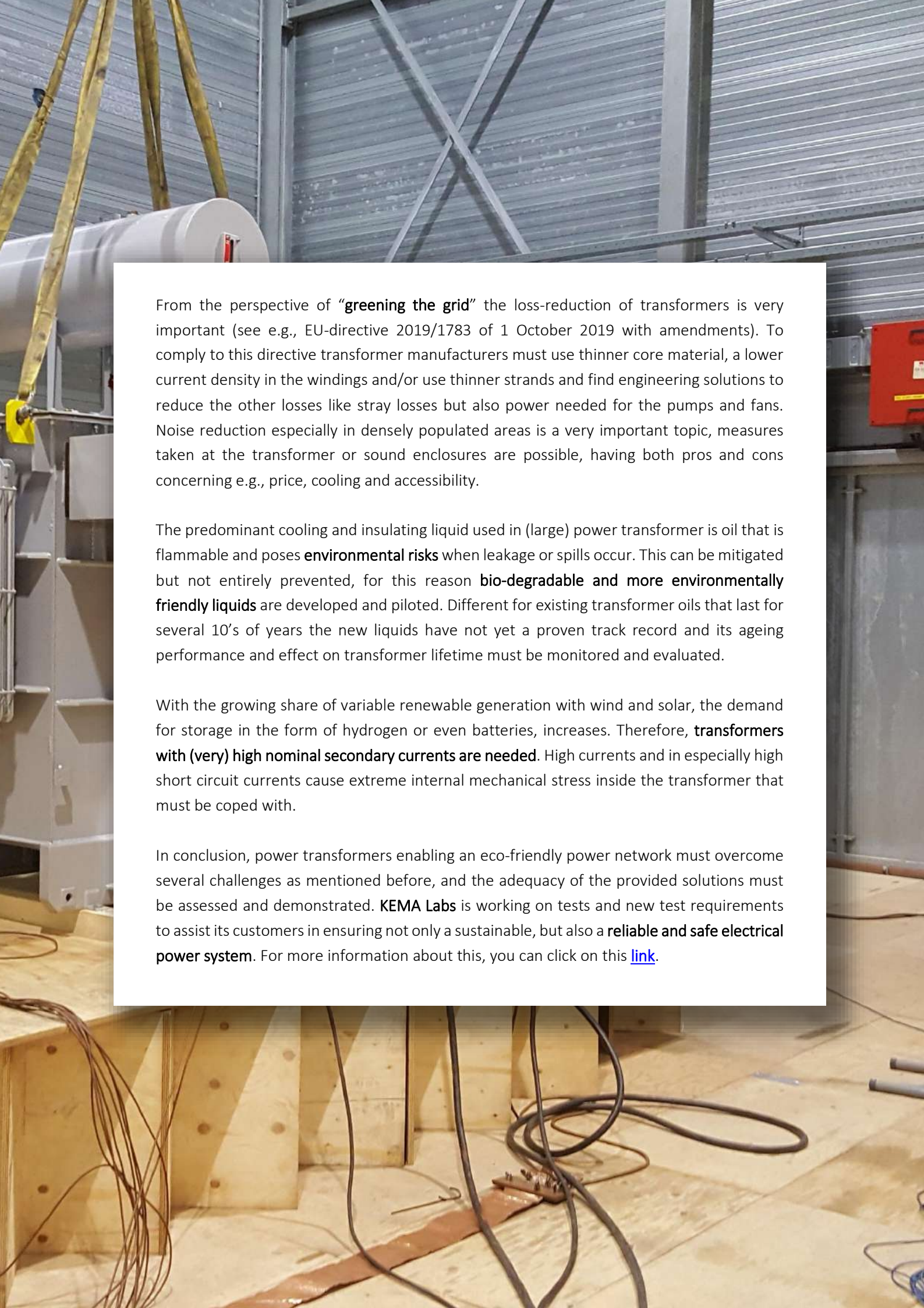
Due to the higher utilization of the grid assets the overload-capability of **grid components** and power transformers becomes more important, and especially for the medium voltage level the (automatic) voltage control due to increased fluctuations of renewable generation and loads as **EV-chargers and heat pumps**.

The power transformer will most likely see more and different transients since the power system becomes more complex, with more power electronic converters coupled to **renewable generation and green hydrogen production**, embedded (HV)DC links, a higher share of transmission done with cables and the faster **digital steering** and control of power flows and reactive power compensation.

If combined with the expected (regional) higher ambient temperatures due to climate change this has implications for the ageing of transformers and most likely more paralleling and high current distribution transformers in solar and electrolyser plants.

Transformer filled with natural ester under test, on the boat





From the perspective of “**greening the grid**” the loss-reduction of transformers is very important (see e.g., EU-directive 2019/1783 of 1 October 2019 with amendments). To comply to this directive transformer manufacturers must use thinner core material, a lower current density in the windings and/or use thinner strands and find engineering solutions to reduce the other losses like stray losses but also power needed for the pumps and fans. Noise reduction especially in densely populated areas is a very important topic, measures taken at the transformer or sound enclosures are possible, having both pros and cons concerning e.g., price, cooling and accessibility.

The predominant cooling and insulating liquid used in (large) power transformer is oil that is flammable and poses **environmental risks** when leakage or spills occur. This can be mitigated but not entirely prevented, for this reason **bio-degradable and more environmentally friendly liquids** are developed and piloted. Different for existing transformer oils that last for several 10's of years the new liquids have not yet a proven track record and its ageing performance and effect on transformer lifetime must be monitored and evaluated.

With the growing share of variable renewable generation with wind and solar, the demand for storage in the form of hydrogen or even batteries, increases. Therefore, **transformers with (very) high nominal secondary currents are needed**. High currents and in especially high short circuit currents cause extreme internal mechanical stress inside the transformer that must be coped with.

In conclusion, power transformers enabling an eco-friendly power network must overcome several challenges as mentioned before, and the adequacy of the provided solutions must be assessed and demonstrated. **KEMA Labs** is working on tests and new test requirements to assist its customers in ensuring not only a sustainable, but also a **reliable and safe electrical power system**. For more information about this, you can click on this [link](#).



DECARBONIZATION

Net-zero emissions electricity grids: Farewell to SF6?

The realization of net-zero emissions electricity grids is the talk of the town, in line with huge efforts in the electricity generation, such as formulated in the European Green Deal. At present, the vast majority (> 95%) of the CO₂ equivalent, produced by T&D networks is due to transmission losses. While the energy generation mix will eventually tend to zero carbon footprint, the remaining CO₂ equivalent will be due to SF₆, stored in T&D equipment. The past decades, it is recognised that SF₆ is the most potent man-made greenhouse gas, having a CO₂ equivalent (Global Warming Potential, GWP) of 25 200. This new, higher number was decided in last month's 6th IPCC Assessment Report.

The global emission rate of SF₆ is estimated (2018) at 9.0 ± 0.4 kt/yr. Taking the global CO₂ emission (2020) of 35 Gt/y, the contribution of SF₆ emission to the

worldwide CO₂ equivalent emission is in the order of several tenths of percent, which is the equivalent exhaust of approx. 100 million gasoline automobiles. Moreover, given the 3200 years of atmospheric lifetime of SF₆ (against CO₂: 300 –1000 years), reduction of SF₆ emission is even more effective than compensating it with CO₂ reduction elsewhere.

As a result, industry is investing heavily to develop SF₆-free equipment. Even competitors join forces (and publicity!), share patents, to realize this in a much shorter period than it took to reach technical maturity of their SF₆ predecessors.

Alternatives to SF₆ in T&D equipment are either based on natural-origin gases (GWP < 1) or consist of a mixture of CO₂, O₂ and a small fraction of fluoronitriles (C₄-FN) or fluoroketones (C₅-FK).

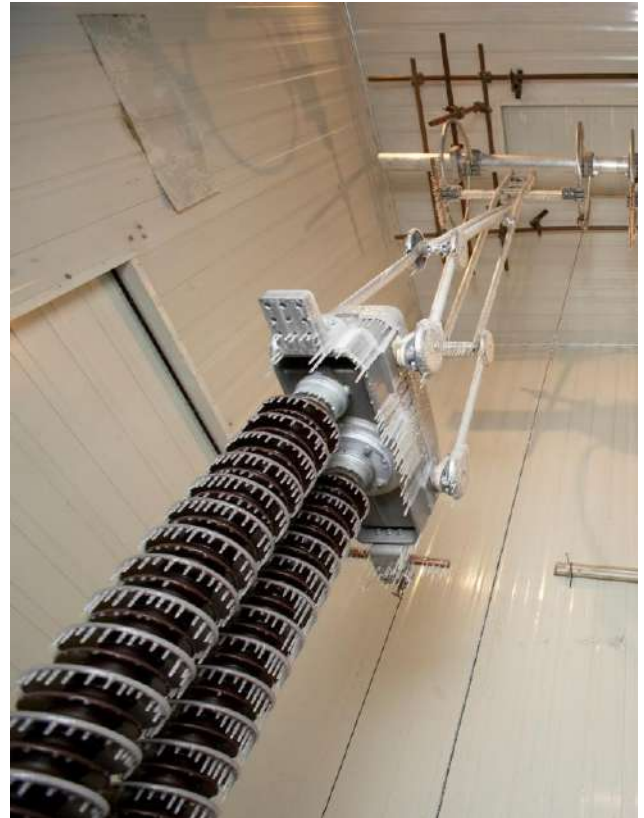
SF6 alternatives serve one of these two functions:

1. Electric insulation. In GIL, GIB and instrument transformers now both natural-origin gas as well as fluorinated mixtures are found up to 420 kV, in one Chinese project even up to 1000 kV.

In switchgear natural-origin gases serve as external insulation of vacuum interrupters. This approach is a long standing one applied in distribution and is now penetrating transmission switchgear up to 170 kV.

2. Switching and electric insulation with a pressurised gas. This is mostly a mixture of CO₂ as a carrier gas, with an addition of O₂ and a synthetic fluorinated compound with a resulting mixture GWP in the range 300 - 750.

At present, this principle can be found in products in a voltage range of 10 –170 kV and is applied in all switchgear: circuit breakers, load break-, (high-speed) earthing- and disconnecting switches. Alternatively, also natural-origin gas circuit breakers exist.



Insulator at KEMA Labs, Arnhem (The Netherlands)

In the 2022 CIGRE conference, various new breakthrough developments will be announced. Later this month, CIGRE WG A3.41 will publish its Technical Brochure on SF₆-free switchgear.

Compared to SF₆, the key parameters of the alternative mixtures are very different. In order to maintain similar geometric footprint with adequate insulation level, the gas pressure must be increased by 2- 3 bar. The carrier gases have smaller molecules, with consequence for tightness, requiring new sealings. Temperature-rise limits are more easily reached. Thermodynamic properties of fluorinated compounds vary which has its consequences for low-temperature application. These compounds are consumed by arcing, and arcing stresses on the internal breaker parts are more severe.

Redesign of all SF6-free equipment is necessary, in order to deal with the higher stresses compared to SF6. The availability of the alternative fluorinated gases is now transferred to most existing manufacturers and is not the exclusive ownership of the product launching manufacturers. Newcomers and start-ups come with innovative prototypes, but only rigorous independent testing can qualify these as solutions.

The multitude of new products can be confusing to system operators. In a poll at CIGRE conference 2021, 80% indicated to plan installation of SF6-free GIS within 5 years, but 72% did not decide yet on a technology. 87% Indicated that the state of technology and experience is insufficient. The willingness to phase out SF6 is clear, but the road towards it seems not clear yet.

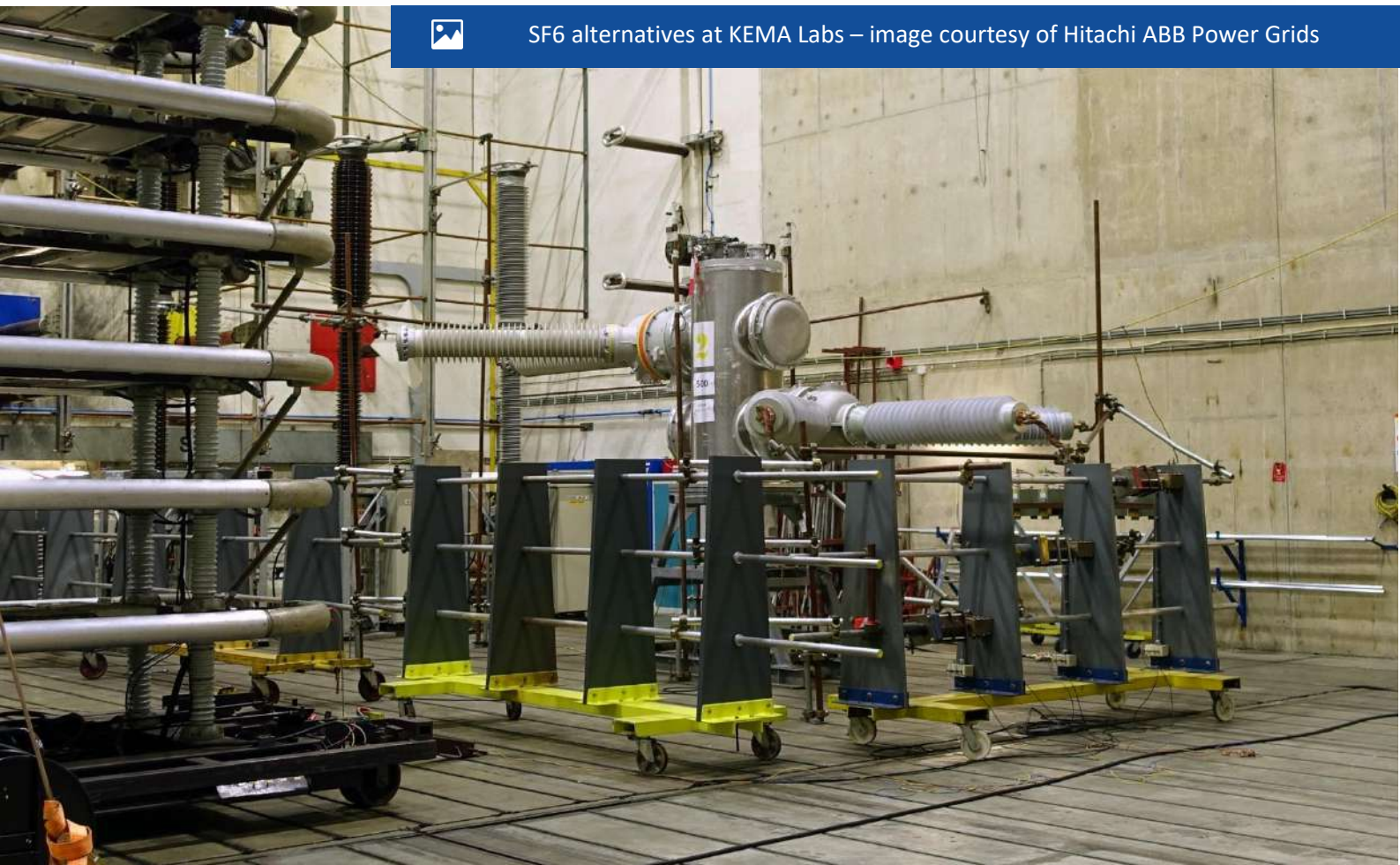
Another uncertainty is created by (future) regulations. Few weeks ago, the European Commission published a proposal, as a follow-up of its F-gas regulation (2014), to prohibit the installation and replacement of fluorinated greenhouse gases in switchgear in stages by voltage rating, until a total prohibition by Jan. 1, 2031. Herein, insulating and/or breaking media having a GWP ≥ 10 are prohibited unless evidence is provided that no suitable technical alternative is available in this range, in which case media up to GWP 2000 are permitted, thus excluding SF6 entirely.

An even stricter (GWP shall be ≤ 1 without “reporting measures”) SF6 phasing-out scheme ending Jan. 1, 2033 was legally adopted in California at the beginning of this year.

Industry is taking SF6 reduction very serious, as the recent publication of ambitious roadmaps towards SF6-free switchgear up to 550 kV demonstrates. System operators take their share in decarbonization by installing equipment, thereby stimulating the development of reliable “green” products, building up an experience database and mitigating the risk of carbon taxation in the future.



SF6 alternatives at KEMA Labs – image courtesy of Hitachi ABB Power Grids



Upcoming events

Power & Energy Africa 2022

May 19-21, 2022



Nairobi, Kenya

The 9th edition of Power & Energy Africa is an imposing demonstration of the importance of a successful development of the power and energy sector in Kenya. Exhibiting at the P&E Africa 2022 event will allow visitors to showcase their products and services to one of the industry's largest gathering of qualified decision-makers.

POWERGEN International

May 23-25, 2022



Dallas, Texas, USA

Power producers, utilities, EPCs, consultants, OEMs, and large-scale energy users gather at POWERGEN International® to discover new solutions as large centralized power generation business models evolve into cleaner and more sustainable energy sources.

ENERGYMEET2022

June 20-22, 2022



Copenhagen, Denmark

ENERGYMEET2022 promotes new Power & Energy engineering techniques information among the International Communities and Industrial heads to discuss the latest developments and innovations in the fields of Power & Energy Engineering with colleagues from different countries.

World Conference on Electrical Engineering

July 15-17, 2022



Amsterdam, Netherlands

This Electrical Engineering conferences 2022 will provide an ideal environment to develop new collaborations and meet experts on the fundamentals, applications, and products related to the fields of electrical engineering and power electronics.

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