Fraunhofer IEE

Impact assessment of F-gas free medium voltage switchgear

Fraunhofer Institute for Energy Economics and Energy System Technology IEE and Grenoble Ecole de Management (GEM) have performed a research study to investigate the impact of the application of the greenhouse gas sulfur hexafluoride (SF6) in power distribution grids. We performed the work between March 2019 and April 2020 focusing on medium voltage (MV) switchgear in electricity grids in the European Union. Participation in the study was open to all electricity grid stakeholders.

The study analyzes the application of SF6 and of fluorinated gas (F-gas) free alternatives in medium voltage grids and intends to support the COP 21 Paris Agreement, and industry's sustainability commitments towards the nature and the planet.

The study comprises two parts:

- modeling of MV switchgear installation development under different boundaries showing the impact on SF6 emissions,
- survey and choice experiment to analyze market acceptance of SF6-free alternatives, as well as barriers and drivers to adoption.

Modeling scenarios of MV switchgear installation development and impact on SF6 emissions

Authors: Wolfram Heckmann and Thorsten Reimann, Fraunhofer Institute for Energy Economics and Energy System Technology IEE

We designed an asset-based model in a bottom-up, grid topology oriented approach for Germany, France and Spain and extrapolated to the EU28 countries. With that, we estimate that around 15 million MV switchgear functional units are installed today of which 10 million are using SF6.

Modeled installed Base 2020	Germany	France	Spain	EU28 (extrapolation)
Number of MV switchgear functional units – total [million]	ca. 3,1	ca. 2,0	ca. 1,7	ca. 15
Number of MV switchgear functional units – use of SF6 [million]	ca. 1,4	ca. 2,0	ca. 1,1	ca. 10
SF6 banked volume in MV switchgear [t]	1300	1100	1200	8600 (196 million t CO2 equiv.)

We estimate the banked SF6 volume in MV switchgear for EU28 today with 8600 t. This is equivalent to about 20% of the yearly greenhouse gas emissions of the EU28 power generation industry. The yearly operation emissions are 0.1% of the banked volume.

The model allows investigating the impact and sensitivity of variable technical parameters (e.g. grid extension, technology market shares, switchgear lifetime) or changes in policy and regulation (e.g. forced replacement) from 2025 until 2050 with an outlook to 2100.

Three main drivers define the development of SF6 emissions in medium voltage switchgear: network extensions, operation emissions, and end-of-life handling. The end-of-life handling has the key role. Network extension effects are also significant.

We expect network extensions due to demand increase but mainly due to the increase in renewable energy installations leading to an increase of about 40% in MV switchgear installations until 2050. Provided a steady market share of SF6 applications this leads to the same increase of the banked SF6 volume and yearly operation emissions. We recommend starting as soon as possible using F-gas free equipment wherever applicable to minimize network extension effects on greenhouse gas emissions.

Considering the European Green Deal and Circular Economy, zero emissions by 2050 regarding the installed base is only achievable by forced replacement of switchgear with F-gas free technology. For the replacement high quality end-of-life handling is the key to minimize greenhouse gas emissions. Regulations for the decommissioning of SF6 equipment are in place but there is uncertainty of the actual implementation and little experience regarding the fractured private market. We expect leakage rates ranging from 1.5% (industry best practice) to 40% (private market worst case) with a best guess of 10% leakages in average during the whole end-of-life process.

Reducing the average leakages from 10% to 5% will reduce the overall emissions by about 460 t SF6 or 40%. The implementation of high quality lifetime management processes and monitoring Europe-wide is essential to minimize the impact of end-of-life leakages before starting forced replacement. While we expect a well-established end-of-life management for utilities and bigger industries, incentives like credits for controlled decommissioning of SF6 equipment could be considered to reach the fractured private market.

Empirical study investigating the environmental and socio-economic impact of SF6 and its alternatives in medium voltage switchgear

Authors: Marie-Charlotte Guetlein and Carine Sebi, Grenoble Ecole de Management

The aim of this study is to better understand customer-purchasing criteria for medium voltage (MV) switchgear, including the interplay of technical, economic as well as environmental aspects. This knowledge can be used to predict market development, in particular with regard to the emergence of SF6-free technologies. Since new alternatives to SF6 have not yet widely penetrated the market, empirical analysis cannot draw on observed adoption behavior to elicit market acceptance of these alternatives. Therefore, a survey including stated preferences choice experiments (SPCE) was carried out among users of primary and secondary MV switchgear as well as intermediaries in different sectors (including utilities, renewable energy, and other private industry sectors). Respondents were selected to be company representatives with knowledge about switchgear and ideally involved in the switchgear procurement process. The survey was completed anonymously by a total of 443 respondents in five European countries.

SPCEs involve constructing hypothetic choice scenarios where alternatives (e.g., products, services) are described by a range of attributes (e.g., price, size). In this study, respondents were successively asked to choose one alternative from a set of MV switchgear alternatives. They were expected to make trade-offs between the attributes characterizing the different MV switchgear alternatives to select their most preferred alternative. This method allows notably eliciting customers' preferences and willingness to pay for different attributes of MV switchgear, including for instance compactness, global warming impact, and absence of F-gases. Furthermore, the declarative survey explicitly investigated barriers and drivers to adoption of SF6-free technologies as well as the role of policies and regulations to promote these technologies from the point of view of MV switchgear users.

Results from the survey suggest that customers for MV switchgear expect a decrease in use of SF6 technology in the near future. This decrease, however, is expected to be primarily driven by policies and regulations, rather than technological change or prices. Customers remain in fact uncertain which technology will most likely replace SF6. Technological alternatives are currently not attractive to many potential customers, mainly because these alternatives require too much space or are too expensive. Against this background, financial incentives (e.g. subsidies) for users of MV switchgear and a complete ban on SF6 are considered the two most useful policies to promote SF6-free MV switchgear by respondents.

At the same time, respondents express an interest in environmental aspects of different MV switchgear technologies. Eco-friendliness was in fact identified as one of the most important purchase criteria for MV switchgear. The fact that customers seem to care about environmental aspects when purchasing MV switchgear suggests that an environmental label for MV switchgear would be valorized if introduced on the market. Such a label could for instance feature an evaluation of the product's global warming impact or be used to certify F-gas free switchgear – two aspects for which respondents in the SPCE were willing to pay respectively 16% and 20% more compared to their usual purchase price.

Detailed results for both parts of the study are available on the project web site www.f-gas-free.eu.

Contact

Fraunhofer IEE
Königstor 59
34119 Kassel, Germany
www.iee.fraunhofer.de

Dipl.-Ing. Wolfram Heckmann
wolfram.heckmann@iee.fraunhofer.de

Grenoble Ecole de Management
www.grenoble-em.com

Marie-Charlotte Guetlein
marie-charlotte.guetlein@grenoble-em.com
Carine Sebi
carine.sebi@grenoble-em.com

Project website: www.f-gas-free.eu

Project details

Project title: Research initiative on SF6 and F-gas free alternatives for medium voltage (MV) gas-insulated switchgear installations in Europe; duration: 03/2019 - 04/2020

Short profile of study partners

The **Fraunhofer Institute for Energy Economics and Energy System Technology IEE** in Kassel researches for the national and international transformation of energy supply systems.

We develop solutions for technical and economic challenges in order to further reduce the costs of renewable energies, to secure the supply despite volatile generation, to ensure grid stability at the usual high level and to make the business model of the energy transition a success.

With the help of our scientific, technical and operational offerings and solutions, we support our customers and partners from politics and industry.

Established by Grenoble's Chamber of Commerce and Industry in 1984, Grenoble Ecole de Management (GEM) is a higher education institution in Management. It delivers 40 national and international programs from the undergraduate to the Doctoral level for about 6000 students. It is accredited by EQUIS, AACSB and AMBA, and a member of the Conférence des Grandes Ecoles. GEM ranks among the 20 best European Business Schools (latest Financial Times Ranking), and typically among the top 4 to 6 business schools in France.

The GEM Energy Management team combines research on strategic management, technology innovation and energy policy to create and share knowledge that will help businesses and society move towards a low-carbon future.