lifeGRID

Cleaner energy · Safer future

LifeGRID aims at developing a 420 kV/63 kA **SF_6-free** High-Voltage (HV) Circuit Breaker (CB) using **GE's g^3 gas** to create the basic solution for SF_6-free HV **gas-insulated substations**

LIFE18 CCM/FR/001096.

The **LifeGRID** project has received funding from the **LIFE Program** of the European Union.

420 kilovolts SF_6 gas-insulated substation

1.1 PROJECT DATA

Project Summary: The LifeGRID project is about developing a 420 kV - 63 kA SF_6 -free high voltage circuit breaker using GE's g^3 gas to create the basic solution for SF_6-free high voltage gas-insulated substations. This project is a key milestone in developing other high voltage switching equipment and, with their deployment, decarbonize high voltage electrical grids.

Coordinating Beneficiary: GE's Grid Solutions SAS (France)
Associated Beneficiaries: Faculty of Electrical Engineering at the Brno University of Technology (Czech Republic), the Leibniz Institute for Plasma Science and Technology (Germany), CEA (France),.

Project Start Date: 01/07/2019
Project Duration: 38 months
Project Budget: M€ 4.045
EU LIFE Contribution: M€ 2.225 (55%)

Contact Details: Yannick Kieffel
GE Grid Solutions
Address: 21 rue de Cyprian
69100 Villeurbanne - France
Email: Yannick.kieffel@ge.com
Website: www.lifeGRID.eu

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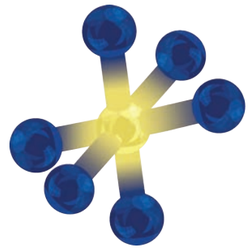
1.2 ABBREVIATIONS AND CHEMICAL FORMULAE

1.2.1Abbreviations

Abbreviations	Translation
CB	Circuit-breaker
HV	High voltage
HVCB	High voltage circuit-breaker
GIS	Gas-insulated substation
GIL	Gas-insulated line
MV	Medium voltage
T&D	Transmission and distribution



2. SF_6 or Sulfur hexafluoride molecule

1.2.2 Chemical Formulae

Chemical Formula	Chemical Name
SF_6	Sulfur hexafluoride
CO_2	Carbon dioxide
O_2	Oxygen
C_4F_7N	Fluoronitrile
g^3	82% Carbon Dioxide + 13% Oxygen + 5% Fluoronitrile g^3 gas is GE's alternative gas to SF_6.

1.3 INTRODUCTION

The LifeGRID project is supported by the European Union. LIFE is a European program-funding initiative to protect the environment and the climate. It encourages projects that enable the use of alternatives to SF_6 with a low impact on the climate. The European LIFE Programme recognizes the potential of GE's g^3 project to help significantly reduce greenhouse gas emissions. GE Grid Solutions thus receives funding from the European Commission as part of its climate action Programme to contribute to the development of a 420-kilovolt (kV) and 63-kiloamperes (kA) gas-insulated substation (GIS) without sulfur hexafluoride (SF_6).

1.4 LIFEGRID PROJECT IN BRIEF

1.4.1 Project objectives

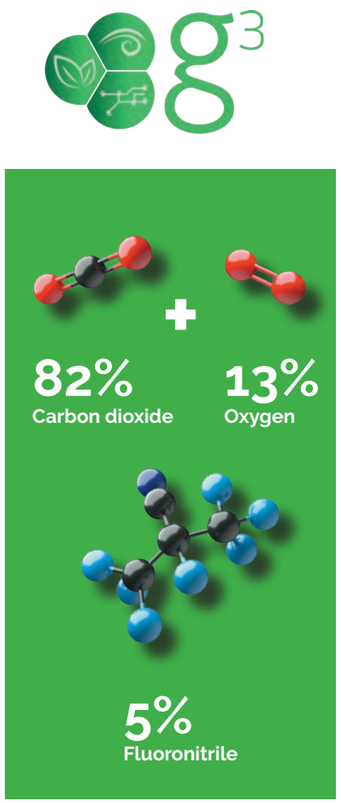
Our objective is to help electrical utilities reduce SF_6 gas on their high voltage networks and move them to environmentally friendly options like g^3 gas. To achieve this target, we must demonstrate that it is feasible to cover all main voltage ranges applied to the European electrical networks with g^3 technology. Our LifeGRID project is a key milestone of this ambition.

The main objective of the project is to replace SF_6 in HV circuit breakers embedded in GIS with a more sustainable alternative, GE's g^3 gas. The technical feasibility was already demonstrated at the 145 kV level. However, the challenge is to scale it up to the highest voltage level in Europe, which is 420 kV. Ultimately, this will demonstrate that an SF_6-free European network is possible.

However, going to higher voltages/currents requires an innovative combination of gas mixture fine-tuning and component adaptations (mainly the circuit breaker interrupting chamber) to show capabilities for a fully integrated future-proof SF_6-free GIS circuit breaker at higher ratings. It also requires a better understanding of the behavior of the g^3 gas mixture and its by-products that currently occur when the circuit breaker is switching. In fact, as an electrical arc occurs during switching, the temperature in the equipment increases drastically, bringing the molecules into a plasma stage which leads to the decomposition of the gas mixture.

The cost of the final product, as well the time-to-market and the duration of the project, also influence the decisions to be made after the first phase of the project.

Finally, a life-cycle assessment of the new g^3 circuit breaker should be carried out to evaluate its positive global impact on the environment. The results will be officially made available in an Environmental Product Declaration (EPD). This will help utilities assess the global impact of their future 420 kV substation projects.



3. g^3 gas is GE's alternative gas to SF_6

1.4.2 Project phases

Phase 1 – Preparatory work

This phase consisted in defining the most appropriate design of the 420 kV SF_6-free GIS circuit breaker (a single- or a double-interrupting chamber) and g^3 gas compound mixture to be used.

To do so, we developed a multi-physics macroscopic numerical simulation model. Numerical simulations are an innovative way to save money, time, and unnecessary assessment on physical components, and thus embedded carbon. However, the results provided by the models must be corroborated with real-life test results to be validated.

As a result, we built a g^3 gas behavior database to obtain the determination of the plasma composition, detailed thermodynamical and radiative data, as well as transport properties, namely dynamic viscosity, thermal conductivity, and electrical conductivity of g^3 gas with various admixtures.

The calculations of the gas mixture properties demand specific equipment and hyper computers. That is why this part of the project was attributed to our two academic partners, the Faculty of Electrical Engineering at Brno University (BUT) in the Czech Republic and Leibniz Institute for Plasma Science and Technology of Greifswald (INP), in Germany.

BRNO UNIVERSITY OF TECHNOLOGY

INP FROM IDEA TO PROTOTYPE

4. LifeGRID academic project partners

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THE METHOD

A completely new database of gas properties in specific conditions was created and applied on the numerical modeling in the circuit breaker. GE engineers worked with Computational Fluid Dynamics (CFD) methodologies as implemented in existing numerical analysis solutions such as ANSYS. They integrated the gas properties database and performed the configuration of a model to complete the realization of the simulations and adjust the circuit breaker design.

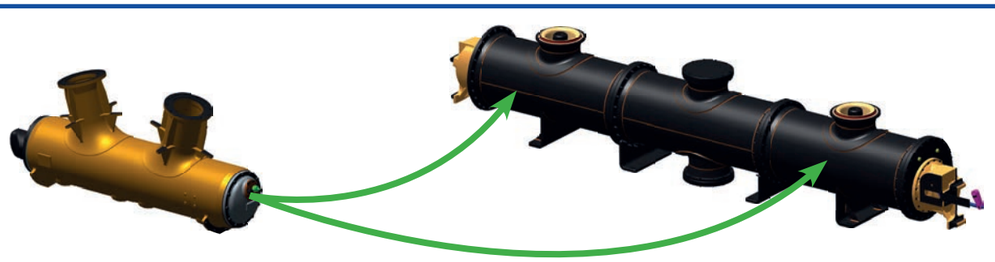
Phase II – Developing the key components of the SF_6-free HV circuit-breaker

In total, more than 1,400 calculations on more than 70 different designs were necessary to figure out which technical adjustments had to be made to achieve this project successfully. This led to the assembly of 12 different prototypes and the demonstration of the main performances according to international standards.

This proved the feasibility of the g^3 technology reaching the highest voltage levels and permitted to switch to its demonstration at a full-scale 420 kV level.

5. LifeGRID team in front of the g^3 GIS circuit breaker that successfully achieved the test phase

6. LifeGRID 420 kV circuit-breaker concept based on two 245 kV interrupting chambers



Our next step was the integration of the two 245 kV – 63 kA interrupters in the full-scale double-chamber GIS circuit breaker

After the design optimization was performed on the 245 kV - 63 kA chamber, we focused on the realization of a pilot of a 420 kV 63 kA double chamber g^3 GIS circuit breaker in order to have an in-depth integration assessment of the apparatus based on utility requirements.

Extensive work on CAD design was performed on the 420 kV - 63 kA double chamber mock-ups to integrate the 245 kV interrupter design and define the best architecture and tank design to connect the two chambers together.

During this phase, we built 10 prototypes that we submitted to the tests defined by IEC standards.
In March 2022, GE was very proud to announce the first SF_6-free 420 kV g^3 GIS circuit breaker during a virtual seminar in front of 90 utility and industry representatives and colleagues.

Phase III - Replicating the technology for other bay components

The LifeGRID 420 kV circuit breaker was developed during Phase I and the first half of Phase II. A GIS embeds other major components such as voltage and current transformers, earthing switches for instance.

The adaptation of these components to the g^3 gas was not part of the project. This was done in parallel, benefitting from the experience and knowledge gained during the first two phases. The development of the 420 kV GIS bay with all g^3 components except the circuit breaker is expected to be finalized at the beginning of 2023. The commercialization of the complete GIS, including the LifeGRID circuit breaker, is planned for the end of 2023.

Scottish & Southern Electricity Networks
TRANSMISSION

Phase IV – Cooperation with a HV network operator to set up a pilot

SSEN Transmission joined our LifeGRID project in 2020. Since then, the Scottish utility has worked closely with GE to help best specify the performance of the circuit breaker.

To support their decarbonization goals, SSEN Transmission awarded a contract to GE's Grid Solutions for the delivery of the world's first SF_6-free 420 kV g^3 gas-insulated substation to be installed at Kintore in Aberdeenshire.

The installation of GE's nine bays of 420 kV g^3 GIS and roughly 2 km of g^3 GIL at Kintore supports SSEN Transmission in getting closer to its carbon reduction targets by building the transmission infrastructure necessary to connect and transport large quantities of renewable energy. It also prevents the addition of about 350,000 tons of CO_2 equivalent on the Scottish grid.

6. Test witnessing by Matthew Barnett from SSEN Transmission in May 2022 in Villeurbanne, France

The contribution of SSEN Transmission was tremendous, bringing customer insights and expectations while witnessing electrical endurance demonstrations to validate the proper operation of the circuit breaker once integrated into the GIS.

This phase will continue after the end of the LifeGRID project until the Kintore substation is energized.

Phase V - Preparing for adoption on all European HV networks

This part of the project was mainly based on the dissemination actions managed by the marketing and communication team of LifeGRID.

Due to the highly competitive context of the project and risks linked to the intellectual property protection, it was difficult to widely communicate about all the steps of the project. As a result, it was decided to focus on the main milestones and celebrate every major success through international press releases or pieces of news using the reach of GE, its press media channels, and social media platforms in parallel with the ones we developed within LifeGRID.

Interactions with the main stakeholders of the project were organized and shared on the website of the project: www.lifegrid.eu.

The main stakeholders, the European HV grid operators, are the ones who will implement the solution at the end. However, it was also very important to share information with other stakeholders such as regulatory bodies, professional associations at European and national level, as well as EU representatives as the EU was preparing the update of its "F-gas" regulation expected in 2023. Numerous interactions through virtual meetings were organized throughout the project.

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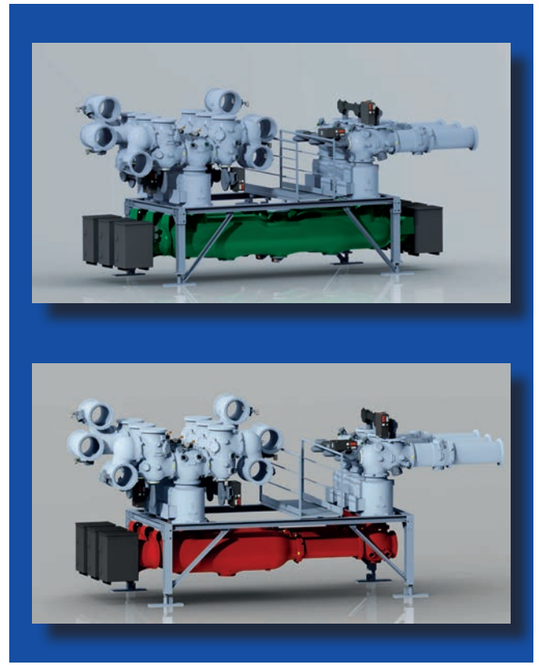
Due to COVID-19 restrictions, we started to organize events mainly during the last year of the project. We participated in two virtual exhibitions, the main one being CIGRE 2021 with a virtual showroom. Our R&D experts also shared the experience of the project with their peers of the Transmission and Distribution sector in CIGRE working groups.

At the end of 2021, we participated in our first in-person conference in Oslo and in August 2022, we finally had the ability to attend CIGRE 2022. We proudly exhibited the results of our LifeGRID project and SF_6-free was the hot topic of the CIGRE conference and working groups.

In 2022, we also organized a virtual event that introduced our new SF_6-free g^3 circuit breaker, which was made public worldwide through a press release.

In parallel to the CIGRE exhibition, we hold a customer seminar with the participation of our customers of course, but also our project partners and some GE Grid Solutions' commercial members who were identified as ambassadors of the technology dissemination in the coming years, the ones who will sell our new SF_6-free g^3 GIS, the T155g.



7. GE's T155g 420 kV GIS bay with SF_6 circuit-breaker or with g^3 circuit-breaker

2. AFTER-LIFE ACTIONS

The After-LIFE period is a continuation of Phases III to V of the LifeGRID project. The years to come will cover the industrialization and the commercialization of the new g^3 GIS.

Industrialization

The industrialization plan is the logical continuation of Phase III (replicating the technology on other bay components). The main action is to complete the integration of the circuit breaker compartment into the 420 kV g^3 GIS bay that was developed in parallel. The other is to prepare the industrialization process. These activities will run during 2023-24 with the objective to be ready to manufacture the 420 kV T155g GIS bays for the Kintore project.

The Kintore Substation

The contract with SSEN Transmission in Scotland plays a major role. The setting of the pilot g^3 gas-insulated substation at Kintore with a first pre-energization in 2025 and final energization of the substation in 2026 will represent a key achievement.

Commercialization

The new g^3 gas-insulated substation bay will be commercially available in 2023 under the name T155g.

Life-Cycle Assessment

An important step to accelerate the adoption of the g^3 technology and our new GIS will be the life cycle assessment (LCA) of the entire 420 kV GIS bay. The LCA will provide utilities with information about the environmental impact of the GIS, which is significant criteria in the selection of future HV equipment as it will take into account all factors, thus not reduce the impact to the gas' GWP. Keeping the same dimensions of the SF_6 GIS avoids the use of additional raw materials, thus associated pollution transfer.

EU's F-gas Regulation

Another important milestone that will determine the future of our new T155g g^3 GIS will be the new EU F-gas regulation expected in 2023. The regulation shall provide both switchgear manufacturers and users a clear long-term visibility on the use of g^3 like mixture to support the implantation of LifeGRID and help to quickly get rid of SF_6.

"This step is a MAJOR one for g³ changing the game for the futureof the electrical grids.

But once it is done, the history will not go backward.

And all people having contributed to the g³ effort will have written an historical chapter in the T&D world. And it does not happen every day. Continue the effort with passion."