The history of gas-insulated substations

From Freon through SF6 towards g³ new insulating and switching gas

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G3 GIS HISTORY

Gas-insulated substations (GIS) represent a key element of high voltage electrical transmission networks thanks to its reliability, low maintenance requirements and compact dimensions. Here is a brief history of its development and pioneers.

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[1966 - DELLE-ALSTHOM first 245 GIS installed at Plessis-Gassot, near Paris in France]

The roots of HV encapsulated substations go back to the metal enclosed concept of the 1920s when oil was used as the insulating medium. Compressed air and different gases were the focus of much research work, and the first Freon-based solution at 33 kV appeared in 1936. The following decades brought new versions until developments in industrial processes, chemistry and physics led the switchgear industry, towards the end of the 20^{th} century, to the use of SF_6 (Sulfur Hexafluoride) for arc extinguishing and insulation as the main GIS technology.

SF_6 gas was already known during the 1940s. Westinghouse holds the original patent for the use of SF_6 as an interrupting medium, and their engineers developed the first applications for switches and circuit breakers in the early 1950s. In the 1960s major manufacturers such as BBC-Calor Emag, Siemens, Magrini, Merlin-Gerin, NEI-Reyrolle, the Japanese and Delle-Alsthom had started intensive developments on the basis of SF_6. The dual-pressure SF_6 circuit breakers of the early GIS systems were soon replaced by single pressure, while circuit breakers were adopting puffer and combined thermal-puffer arc extinguishing chambers. The GIS focus was on the benefits of a compact indoor solution, protected from the environment and closer to users, whereas some markets preferred outdoor rugged solutions using hybrid GIS solutions.

The GE contribution

Grid Solutions, a business of GE Renewable Energy, has a rich GIS development history through its ancestor companies, Delle-Alsthom, Sprecher & Schuh, GEC and AEG.

Delle-Alsthom France started GIS development in 1958 and in 1966-1967 delivered a world's first with its “Fluobloc” at 245 kV in several Paris substations, demonstrating the benefits of underground GIS to supply bulk power close to city users. Achievements in the higher voltage ranges were subsequently marked by the deliveries of the first substations for 420 kV in 1976 and for 550 kV in 1977. Another “world first” was the completion of AEP’s 800 kV GIS in Joshua Falls in 1979.

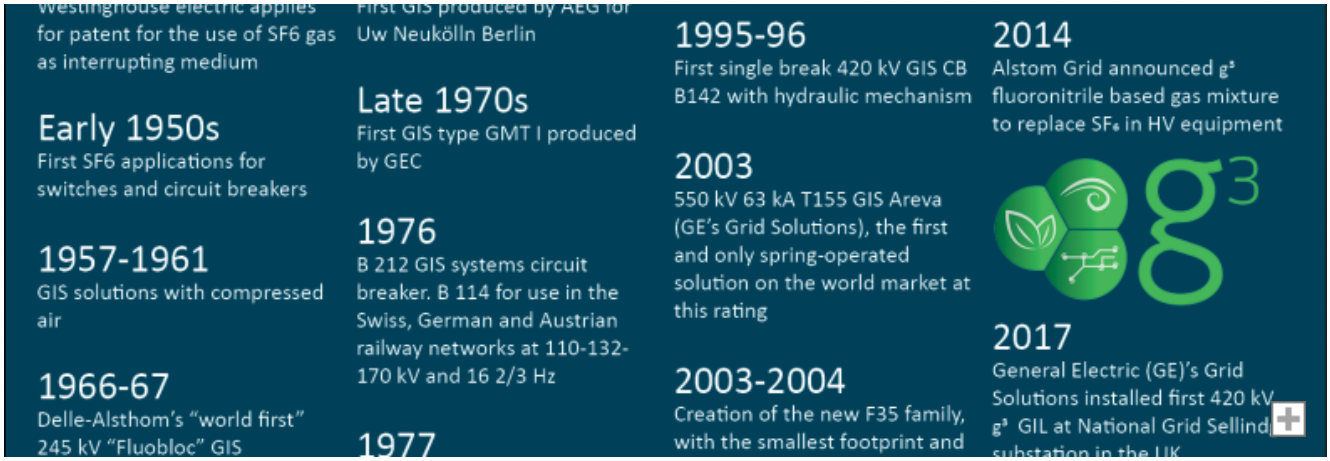
Sprecher & Schuh studied compact metalclad installations as early as 1954 with oil insulation systems, but soon concluded that SF_6 gas insulation offered greater advantages. Their first GIS for 220 kV was delivered in 1970 and the 145 kV, 40 kA in 1971. The original circuit breakers with double pressure SF_6 systems (220 kV, 50 kA), developed together with ITE USA, were operated by the well-known Sprecher motor-wound spring operating mechanisms, which contributed to the success of subsequent GIS families. The exclusive third-generation FK mechanism today serves all Grid Solutions' GIS products in applications around the world.

AEG in Germany has also long been involved in GIS and SF_6, with its first GIS substation delivered in 1971.

Meanwhile, GEC in England was collaborating with Siemens, and their first GIS was a 145 kV substation in London in 1982. As GIS systems developed and their extensive use in HV networks grew, Grid Solutions became the manufacturer of complete GIS ranges of 72.5-800 kV in which single-phase and three-phase encapsulation was and continues to be used.

Looking ahead

Clearly, the most significant development factor was the adoption of SF_6 as an insulation medium. This boosted the development of smaller switchgear requiring less operating energy and reduced materials and resources, leading to higher performance. So far 420 kV, 63 kA with a single break is possible with the spring mechanism.



After 50 years in the making, GIS development is accelerating thanks to the availability of simulation tools and the capability to integrate environmental needs into the design. Future trends could be influenced by the substitution of SF_6 technology, which, however, is likely to be a very complex task. Other steps have already been taken. Moving HV substations closer to consumers results in reduced transmission losses. Indoor GIS reduce the environmental influences on the switchgear, reducing maintenance needs and increasing lifetime. More and more "intelligence" is integrated into the GIS using electronic devices, forming part of digital substations. Ecological and economic considerations, together with ongoing technological developments have made even further optimisation of GIS conceivable.

Moving to SF_6-free technology with g^3 gas, a new era for GIS

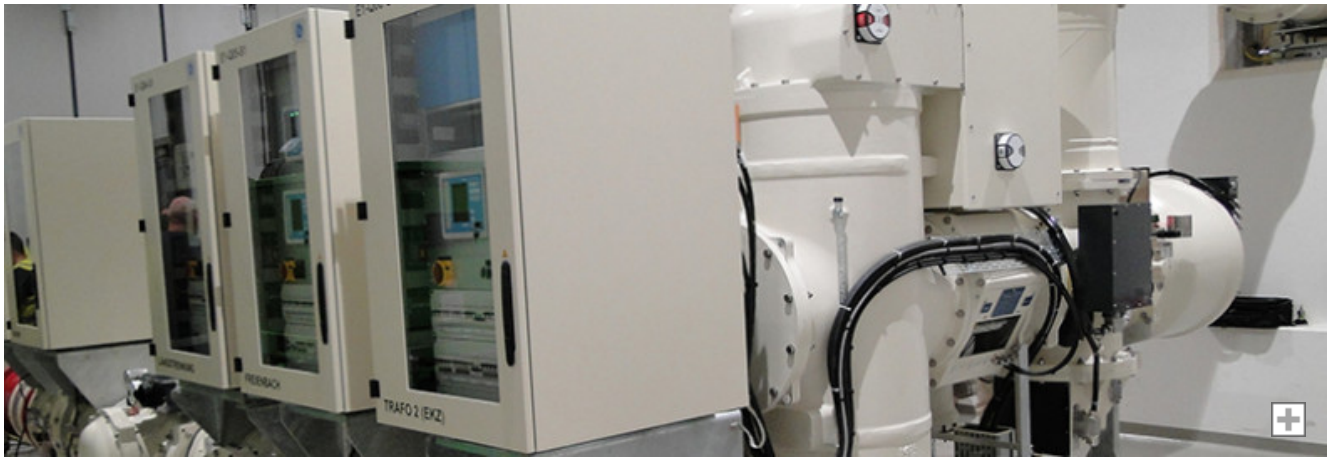
Our ancestor, Delle-Alsthom, pioneered one of the very first

SF_6 GIS in 1966. Because of its outstanding dielectric and physical properties, this SF_6 gas has become the norm over the last 50 years. However, SF_6 was identified as a very potent greenhouse gas, being 23,500 more potent than CO_2 and lasting over 3,200 years if released in the atmosphere. Due to its potential environmental impact, SF_6 was listed has been listed on the Kyoto protocol since 1997. At that time, there wasn't any alternative to SF_6 they concluded. In 2008 GE's Grid Solutions R&D experts in Villeurbanne, France, started working on an alternative in collaboration with 3M™. In 2014, at the Cigré technical conference in Paris, France, they announced g^3 (pronounced g-cubed), a game changing gas mixture based on 3M™ Novec™ 4710 Dielectric Fluid from the fluoronitrile family developed by 3M™ and used as an additive to carbon dioxide and oxygen. Time has come for the experts in Villeurbanne, Aix-les-Bains in France, Oberentfelden in Switzerland, and in Charleroi, PA, to develop the associated products. The first SF_6-free products based on g3 where the gas-insulated lines and busbars are passive components of the GIS. g^3 was used here as the insulating medium. "The first 420 kV g^3 GIL installation was at National Grid's Sellindge substation in the UK in April 2017," explains Bertrand Portal, g^3 Product Manager at GE's Grid Solutions. "The g^3-gas insulated line has been in successful operation since then". In parallel the experts were working on the development of the first 145 kV g^3 GIS. This new g^3-GIS was introduced during Cigré in Paris in 2016 and subsequently energized in Switzerland at Axpo's Etzel substation in 2018. Since then, more than 100 bays have been installed in Europe and the g^3 experts continue to develop new solutions utilizing this alternative insulation and switching gas. In particular, development efforts are focused on a 420 kV g^3 gas-insulated substation and consequently the development of a 420 kV interrupter using g^3 for arc

quenching. Named as the LifeGRID project, this current development effort is being co-funding by the EU Commission's LIFE Programme. The LIFE Programme is the EU's funding instrument for the environment and climate action. In parallel with the circuit breaker development, they will finalize the 420 kV g^3 GIS. This will be a major milestone to build an SF_6-free European grid.

Last, but not least, on April 21st, 2021 GE's Grid Solutions announced a non-exclusive, cross-licensing agreement with Hitachi ABB Power Grids Ltd., granting them use of the g^3 technology to develop a part of their high voltage SF_6-free switchgear portfolio.

"The future of GIS is GE's g^3 fluoronitrile based gas mixture," concludes Portal."



[2018 - GE's first 145 g^3-GIS installed at Axpo's Etzel substation, in Switzerland]

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