

EconIQ Technology Eliminating SF₆ in High-voltage Switchgear and Circuit-breakers

Significant progress has been made in recent years to decarbonize electricity generation through the increased build-out of renewable energy, such as solar and wind. However, addressing greenhouse gas emissions from the transmission and distribution portion of the energy value chain has proved to be a challenge as well. Eliminating SF₆ use in high-voltage electrical substation equipment, including circuit-breakers and gas-insulated switchgear, will be the key to achieving net-zero and enable more sustainable grid operations. SF₆ is one of the most potent greenhouse gases known to man and has a global warming potential 25,200 times higher than CO₂. When leaked, it remains in the Earth's atmosphere for 3,200 years. This article discusses how Hitachi Energy is helping to accelerate the industry's transition away from SF₆ with eco-efficient EconIQ technology.

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1. Introduction

Electrical substation equipment is often subjected to extreme mechanical, electrical, and thermal stress during operation. This is particularly the case with high-voltage circuit-breakers and switchgear. As an example, the temperature inside a 420-kV circuit-breaker, which is typically required to interrupt fault currents of 63,000 A, can reach more than 20,000°C (approximately 36,000°F). The energy released during the interrupting process is comparable to that of a car coming to a complete stop from 100 km/h⁽¹⁾.

The harsh conditions demand an insulating gas with extremely high dielectric strength and interrupting capacity. Sulfur hexafluoride (SF₆) is a synthetic fluorinated compound that possesses both of these characteristics and has been prominent in electrical grids across the globe since the 1950s. In 1997, the Kyoto Protocol identified SF₆ as one of six main greenhouse gases (GHGs) that should be monitored and mitigated. Over the last two decades, significant time and financial resources have been invested by equipment manufacturers to develop more sustainable alternatives to SF₆. However, finding a solution with similar performance characteristics and comparable equipment footprint has been a challenge.

2. The Search for an SF₆ Replacement

Over the years, various alternatives to SF₆ have been developed and tested in high-voltage applications, some with more success than others. In recent years, vacuum circuit-breakers combined with synthetic air as the insulating gas have been touted as one of the leading candidates to replace SF₆. Synthetic air has a global warming potential (GWP) of zero. However, it has only modest dielectric properties. This typically leads to metal-enclosed switchgear such as gas-insulated switchgear (GIS) being larger and heavier than equipment that uses SF₆ (or other advanced alternative gas mixtures).

The size of high-voltage GIS is important for several reasons. Firstly, substations tend to be near urban centers, where available space is often limited. Secondly, if more materials and energy must be used during the manufacturing process, any carbon footprint reductions achieved by using synthetic air are offset.

Fluoronitrile (C₄-FN)-based gas mixtures have emerged as a more effective solution for high-voltage equipment, especially metal-enclosed switchgear including GIS, gas-insulated lines (GILs), dead tank breakers (DTBs) and

hybrid switchgear. Pure C₄-FN has twice the dielectric strength of SF₆. When mixed with carbon dioxide (CO₂) and oxygen (O₂), its CO₂ equivalent is nearly 100 times less than SF₆. Other key advantages include:

- (1) Equipment using the C₄-FN-based mixture is as compact as existing SF₆ products with identical ratings
- (2) It is scalable to higher voltages
- (3) It is as reliable as SF₆
- (4) It delivers the lowest total carbon footprint

3. How Hitachi Energy Is Pioneering SF₆-free Technology

Hitachi Energy is a global leader in the development of sustainable switchgear solutions and has made substantial progress over the past two years to commercialize high-voltage products that utilize the new C₄-FN-based gas mixture.

In 2021, following a collaborative, cross-licensing agreement with GE Renewable Energy’s Grid Solutions, Hitachi Energy launched a new line of eco-efficient, high-voltage switchgear products known as EconiQ⁽²⁾. Multiple high-voltage SF₆-free EconiQ products have already been installed across the globe, including 72.5-kV and 145-kV

live tank breakers (LTBs) and 145-kV GIS, as well as 420-kV GILs and EconiQ retrofill.

In late 2022, an important milestone was reached with the introduction of a 420-kV and 63-kA SF₆-free circuit-breaker. Circuit-breakers of this rating are particularly important for power transmission over long distances. The commercialization of an SF₆-free alternative is important, as it will unlock new decarbonization pathways for transmission system operators (TSOs). The circuit-breaker has passed all relevant tests described in the International Electrotechnical Commission (IEC) and Institute of Electrical and Electronics Engineers (IEEE) standards for 63 kA, 5000 A, 50 and 60 Hz. Its footprint is also comparable to that of SF₆-based 420-kV circuit-breakers.

Hitachi Energy’s plan is to expand the SF₆-free portfolio across the entire high-voltage switchgear range in the coming years (see Figure 1).

4. Project References

Several installations of the EconiQ 420-kV SF₆-free circuit-breaker are slated in the coming years. Some of Hitachi Energy’s recent project announcements are outlined below.

Figure 1 — EconiQ High-voltage Portfolio Roadmap

Hitachi Energy’s plan is to expand the SF₆-free technology across the entire high-voltage product range in the coming years.

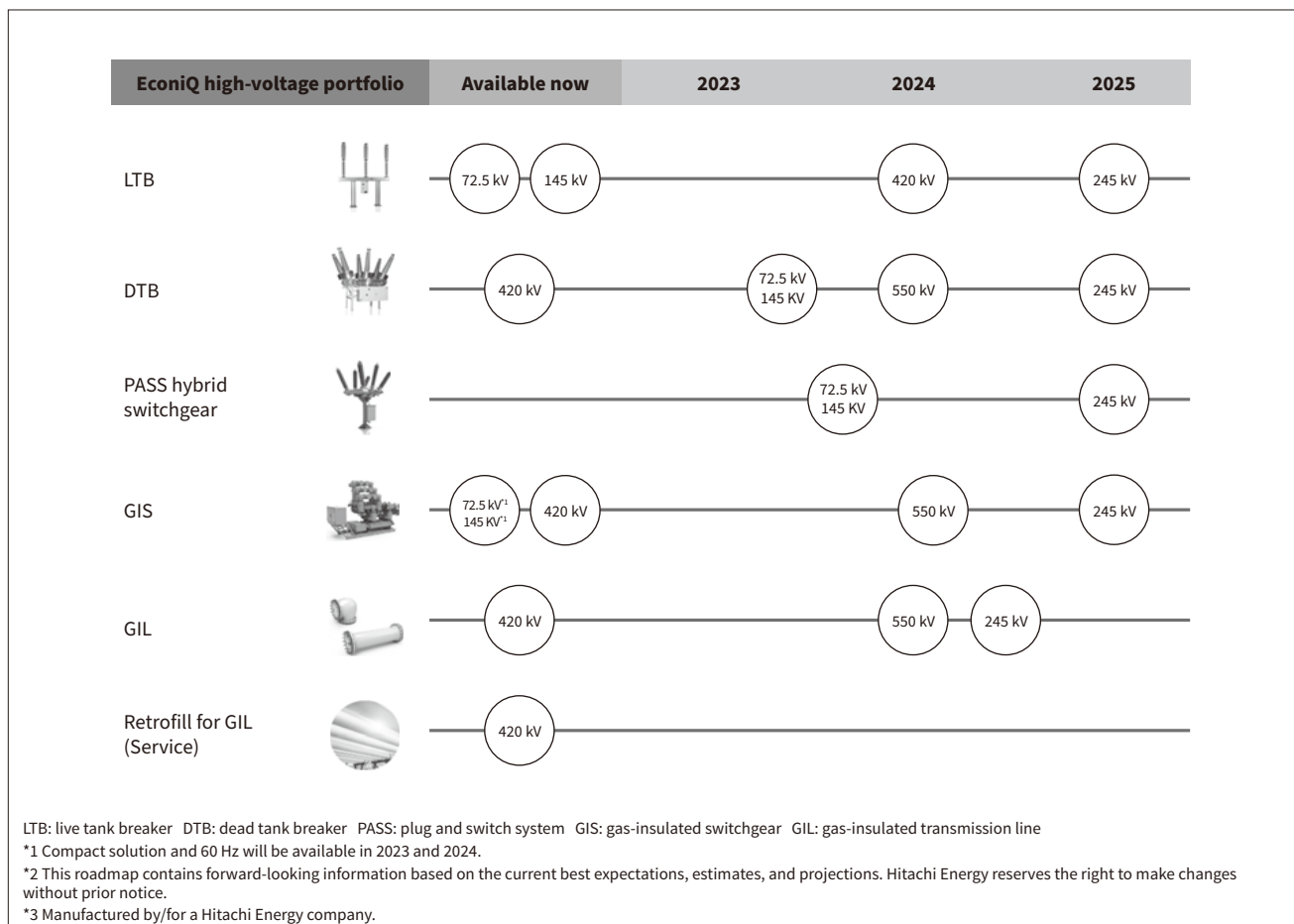
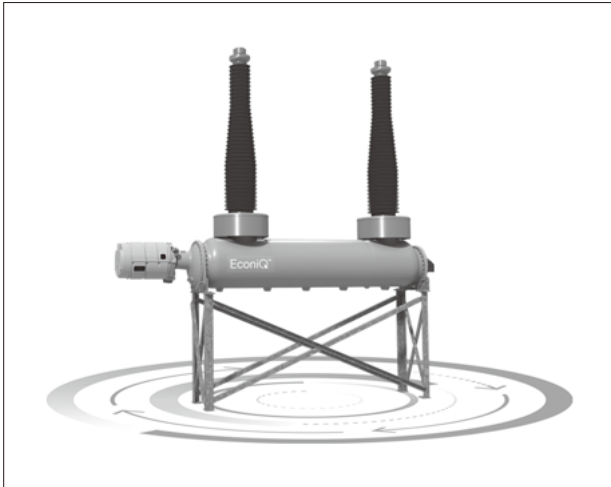


Figure 2 — EconiQ 420-kV DTB

The first installation of the 420-kV SF₆-free circuit-breaker in a dead tank breaker (DTB) application will take in place in a 345-kV transmission system in the USA.



(1) USA

The first installation of the 420-kV circuit-breaker is scheduled to take place in late 2023 in the USA, where it will be used as a DTB in a 345-kV substation (see **Figure 2**). The operator of the substation, Eversource Energy, serves approximately four million customers in the Northeast region. The project will play a key role in helping Eversource drive sustainability initiatives, one of which is to achieve carbon neutrality in its operations by 2030.

(2) Germany

Another installation of the EconiQ 420-kV circuit-breaker in Germany will be the first application of the circuit-breaker in a GIS. Hitachi will install three bays of GIS at a substation on TenneT TSO GmbH's power grid. The project will allow for the avoidance of approximately 2,300 kg of SF₆, which equates to CO₂ emissions from over 1,100 passenger vehicles annually. The project's expected completion date is 2026.

(3) UK

Hitachi Energy and Linxon UK Ltd. are collaborating to strengthen London Power Tunnels, a key power infrastructure project that will ensure reliable, clean electricity supply for England's capital city. To support National Grid in accelerating its net-zero targets, Hitachi Energy will deliver EconiQ 420-kV SF₆-free GIS and GILs. As one of the world's largest investor-owned transmission and distribution utilities, National Grid has the ambition to remove all SF₆ from its fleet by 2050.

5. Conclusions

Utilities and TSOs have historically been risk-averse when it comes to the implementation of new technologies. This is not without good reason, as grid stability and availability are

of the utmost importance. As penetration from renewables like wind and solar continues to increase, existing transmission and distribution infrastructure will have to be expanded and adapted. Typically, power from a wind farm travels a much further distance to the end-user when compared to a conventional generating source. As a result, there will be a growing demand for higher voltage systems and more substations. While the requirement for high reliability will remain a top priority when building out new infrastructure, the growing focus on sustainability means that GHG emissions must also be considered.

The elimination of SF₆ from high-voltage equipment is now widely accepted by both industry and governments as being an important step toward reaching net-zero. Among all alternatives, C₄-FN-based technology has proved to be the solution to replace SF₆ in high-voltage equipment. Total carbon footprint comparisons favor C₄-FN-based gas technology over the high-voltage GIS using pressurized air as the insulating medium. The technology has gained traction in recent years as large industry players across the globe, including in Europe, China, and Korea, are already using the C₄-FN-based mixture in their equipment.

Hitachi Energy's objective is to have the EconiQ technology in place across its entire high-voltage product range before the end of the decade—demonstrating the scalability of the portfolio and further strengthening the company's position as a sustainable technology leader within the industry.

References

- 1) "Breaker Breakthrough: Q and A with Markus Heimbach, Managing Director, High Voltage Products, Hitachi Energy," *Modern Power Systems* (Aug. 2022), <https://www.modernpowersystems.com/features/featurebreaker-breakthrough-9967621/>
- 2) Hitachi Energy, "EconiQ™," <https://www.hitachienergy.com/us/en/sustainability/econiq>

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