



GARIP Eco: Hitachi Energy's next-generation transformer bushings for SF₆-free substations

Fluoronitrile-based (C₄-FN) gas mixtures, combined with synthetic and natural ester transformer fluids, are increasingly recognized as valid alternatives for SF₆

The global transmission and distribution sector is undergoing one of the most significant technology transitions in decades: the progressive elimination of sulfur hexafluoride (SF₆). Widely used for its excellent dielectric and arc-quenching properties, SF₆ also has a global warming potential 23,500 times higher than CO₂. Its use is now restricted by regulatory frameworks such as the EU F-gas regulation, and utilities worldwide are accelerating their roadmaps to move toward eco-efficient alternatives.

Next-generation insulating media, including fluoronitrile-based (C₄-FN) gas mixtures, combined with synthetic and natural ester transformer fluids, are increasingly recognized as valid alternatives. However, these dielectric insulation media behave differently from SF₆. They operate at higher filling pressures (up to 11 bar versus the ~5 bar typical of SF₆ systems), present new thermal characteristics, and require knowledge of their chemical behavior and material compatibility. Similar to understanding ester oils, which have distinct chemical interactions compared to mineral oil. As a result, every interfacing component

must be re-engineered - not least **transformer bushings**, which represent one of the most critical points of interconnection between transformers and GIS/GIL systems.

A purpose-built RIP bushing

Hitachi Energy developed GARIP Eco to meet these evolving challenges. It extends the proven performance of the GARIP® resin-impregnated paper (RIP) platform - long recognized for its excellent dielectric performance, solid construction, and thermal stability - into the eco-efficient grid era.

GARIP Eco is specifically designed for SF₆-free GIS and GIL applications. It is engineered to withstand elevated operating pressures, maintain dielectric safety under C₄-FN and CO₂ mixtures,

and ensure reliable long-term sealing performance when connected to ester-filled transformers. With advanced coatings and optimized gasket systems, it minimizes leakage risks while delivering robust insulation performance over decades of service.

Key technical features include:

- Dielectric reliability validated for eco-efficient gases (C₄-FN/CO₂ blends).
- Pressure integrity through optimized mechanical design and sealing.
- Compatible materials for eco-efficient gases (C₄-FN/CO₂ blends).
- Excellent thermal performance validated in eco-efficient gases (C₄-FN/CO₂ blends).
- Moisture resistance intrinsic to RIP technology, minimizing partial discharges.
- Interoperability for both retrofit and new GIS/GIL installations.

These features collectively make GARIP Eco not simply a derivative of existing bushing technology, but a new design concept tailored to the eco-efficient substation of the future.

Hitachi Energy collaborated closely with National Grid to design and qualify GARIP Eco bushings at 420 kV and 145 kV

GARIP Eco solves a system-level bottleneck: how to ensure safe and reliable transformer-to-GIS/GIL connections in SF₆-free substations

Case Study: World's first application for UK National Grid's London Power Tunnels Project

The first real-world validation of GARIP Eco came in the London Power Tunnels project, one of the UK's largest electricity infrastructure programs. At the heart of this initiative is the Bengeworth Road 400 kV substation, a compact, underground installation designed to future-proof London's transmission system while minimizing environmental impact.

Here, ester-filled transformers are directly connected to Hitachi Energy's EconiQ™ SF₆-free GIS and GIL systems, creating a pioneering SF₆-free ecosystem at transmission voltage levels. A central engineering challenge was ensuring the reliable interface between transformer and GIS: conventional RIP bushings optimized for SF₆ could not provide the required dielectric margins (longevity) or sealing performance at higher gas pressures.

Hitachi Energy collaborated closely with National Grid to design and qualify GARIP Eco bushings at 420 kV and 145 kV, which successfully passed rigorous testing and field validation. The project demonstrated stable dielectric performance under high-pressure C4-FN mixtures, reliable operation at ester-gas interfaces without leakage or material degradation, and consistent low partial

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discharge activity even under elevated stress conditions.

Beyond technical compliance, GARIP Eco directly supported the project's sustainability targets. The compact GIS footprint reduced material consumption, while the switch to SF₆-free technology significantly lowered the project's carbon equivalent emissions. National Grid also reported biodiversity benefits from the project, further enhancing its contribution to environmental objectives.

The London Power Tunnels case study proved GARIP Eco's capability as a mission-critical enabler for utilities transitioning to SF₆-free grids, setting a precedent for large-scale deployment.

A bridge to the decarbonized grid

From an engineering perspective, GARIP Eco solves a system-level bottleneck: how to ensure safe and reliable transformer-to-GIS/GIL connections in SF₆-free substations.

For utilities, this translates into future-proof assets that fully comply with upcoming SF₆ bans and regulatory requirements, high reliability based on

decades of proven RIP technology adapted to new dielectric conditions, and design flexibility that enables compact, low-carbon substations ideally suited for urban or space-constrained locations.

GARIP Eco also supports OEMs and project developers by offering a standardized, field-tested solution for eco-efficient systems, removing one of the key barriers to SF₆-free adoption at high voltage levels.

Future-ready starts with fit-for-purpose

GARIP Eco is not simply an incremental product evolution; it is a strategic bridge technology. By combining decades of experience with RIP bushings and the latest requirements of eco-efficient substations, Hitachi Energy has delivered a solution that enables utilities to accelerate the phase-out of SF₆ without compromising safety, performance, or reliability.

Its successful implementation in the London Power Tunnels project demonstrates the readiness of GARIP Eco for real-world deployment. As utilities and regulators push toward decarbonization targets, GARIP Eco stands as a critical innovation, helping define the next generation of sustainable transmission networks.

Explore GARIP Eco:

