Gas-insulated transmission lines (GIL)

High-power transmission technology

Answers for energy.

SIEMENS

GIL flexibility: above- or belowground

Second-generation gas-insulated lines for high power transmission are the best option where environmental or structural considerations rule out the use of overhead transmission lines. The outstanding features of a GIL system are its high transmission capacity, superior electromagnetic compatibility (EMC) to any other transmission system, low losses, high safety (no fire hazard) and flexible installation options. GIL can be laid aboveground, installed in tunnels or buried directly in the soil, depending on individual requirements.

GIL – high-power transmission technology

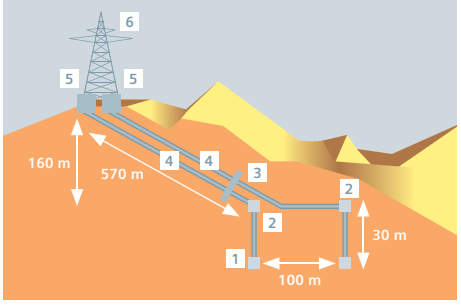
Superior technology and excellent knowhow ensure quality and reliability
Siemens GIL systems are based on the successful SF_6 tubular conductor technology, which has been around for several decades. GIL consist of a central aluminum conductor with a typical electrical cross section of up to 5,300 mm^2. The conductor rests on cast resin insulators, which center it within the outer enclosure. This enclosure is formed by a sturdy aluminum tube, which provides a solid mechanical and electrotechnical containment for the system. To meet up-to-date environmental and technical aspects, GIL are filled with an insulating gas mixture of mainly nitrogen and a smaller percentage of SF_6. For increased lifetime, the "performance line" product series has a longitudinal particle trap installed over the entire horizontal route section. An automated orbital welding procedure, accompanied by tailored ultrasonic inspection techniques, ensures perfect gastightness of the aluminum tubes.

During service, the fully encapsulated design fully protects the GIL against environmental influences. Thanks to the technologically clear-cut, logical design and the use of high-quality materials, an absolutely maintenance-free product is achieved which requires external inspection only. And at the end of its service life, the issue of de-installation is solved. The GIL tubular system with all its components and the insulation gas mixture are 100 percent recyclable. These factors help to minimize lifetime costs.

Impressive practical record: GIL system in Germany's Wehr power plant
Siemens installed a GIL in a tunnel in the Wehr pumped-storage power station in the Black Forest as long ago as 1975. With a single-phase length of almost 4 km this installation is still a significant reference among worldwide GIL projects. Notwithstanding its service time, an inspection after 30 years showed that all components were still in top condition, and assured the customer that GIL will provide many more years of reliable operation.

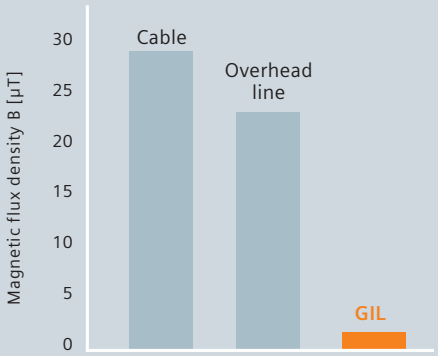
Wehr power plant, Germany

1. 600 MVA transformer
2. Encapsulated surge arresters
3. Transfer switching units
4. GIL connection
5. Open-air surge arrester
6. Overhead line



High EM compatibility

Magnetic fields in microtesla (µT) for GIL, overhead transmission line and cable (XLPE, cross-bonding) for a 400 kV double system at 2 x 1,000 MVA load, GIL and cable laid at a depth of 1 m.



A comparison of the magnetic fields for different high-voltage transmission systems.

Flexible grid connections – optimum grid integration

GIL systems consist of a manageable number of modular elements which can be combined according to defined technical rules. Thus GIL systems are not limited in their entire length. Moreover, they are suited for almost any kind of routing, for instance through built-up areas or road crossings, on marshy ground, etc. To meet these requirements the actual installation of GIL makes use of sophisticated laying techniques. These techniques are based on the well-proven procedures of the pipeline construction industry, adding some product-specific modifications. Consequently project implementation time can be kept to a minimum.

Due to their outstanding design features Siemens GIL are remarkably flexible for different applications. Thanks to their transmission capacity and low losses GIL can be linked directly, one-to-one to overhead lines, continuing the lines underground. As a result of the low electrical capacitance of GIL, compensating reactors are generally not required, even for very long GIL sections of up to 70 km. The technical particulars of Siemens GIL allow for an autoreclosure pattern for the OHL, so that no modification of the protection concept is needed. For the same reasons, GIL are also perfectly suitable for direct connection to substations or transformers.

Outstanding safety in operation

GIL systems by Siemens live up to their reputation not just with their technical specifications, but also by providing excellent operational safety. GIL systems are immune to hazards that are inherent to other power transmission systems. They are safe to touch in operation, as their housing is solidly grounded. They are fireproof and explosion-proof. The electrical insulation system is not subject to aging phenomena, which reduces the risk of internal failures to virtually zero. Siemens GIL are constructed employing separate gastight compartments of variable length, which further increases safety in case of an external impact. GIL systems are gastight and sealed for their lifetime. Consequently they retain their superior operating properties throughout their service life.

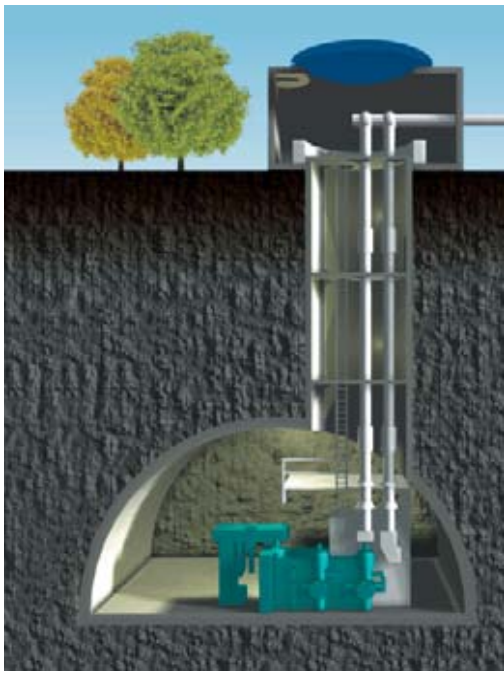
Excellent electromagnetic compatibility enables flexible route planning

The construction of the GIL results in much smaller electromagnetic fields – as much as 15 to 20 times smaller – than with conventional power transmission systems. This makes GIL suitable for completely new routings through populated areas (e.g. next to hospitals or residential areas, in the vicinity of flight monitoring systems, etc.). GIL can be laid in combined infrastructure tunnels together with foreign elements (e.g. close to telecommunication equipment). Thus, GIL provides maximum flexibility for the planning of transmission networks in EMC-sensitive environments, where magnetic fields have to be avoided. Siemens GIL systems satisfy the most stringent magnetic flux density requirements, for example, the Swiss limit of 1 µT.

Flexibility for your success

Due to their unique properties GIL systems have become well established in all parts of the world, to solve difficult transmission tasks in complex routings.

GIL installations have been realized in every conceivable layout, with shafts mastering straight vertical distances of 200 m, overcoming steeply inclined slopes, passing around buildings both above- and belowground, and smoothly following serpentine routings without angle units.

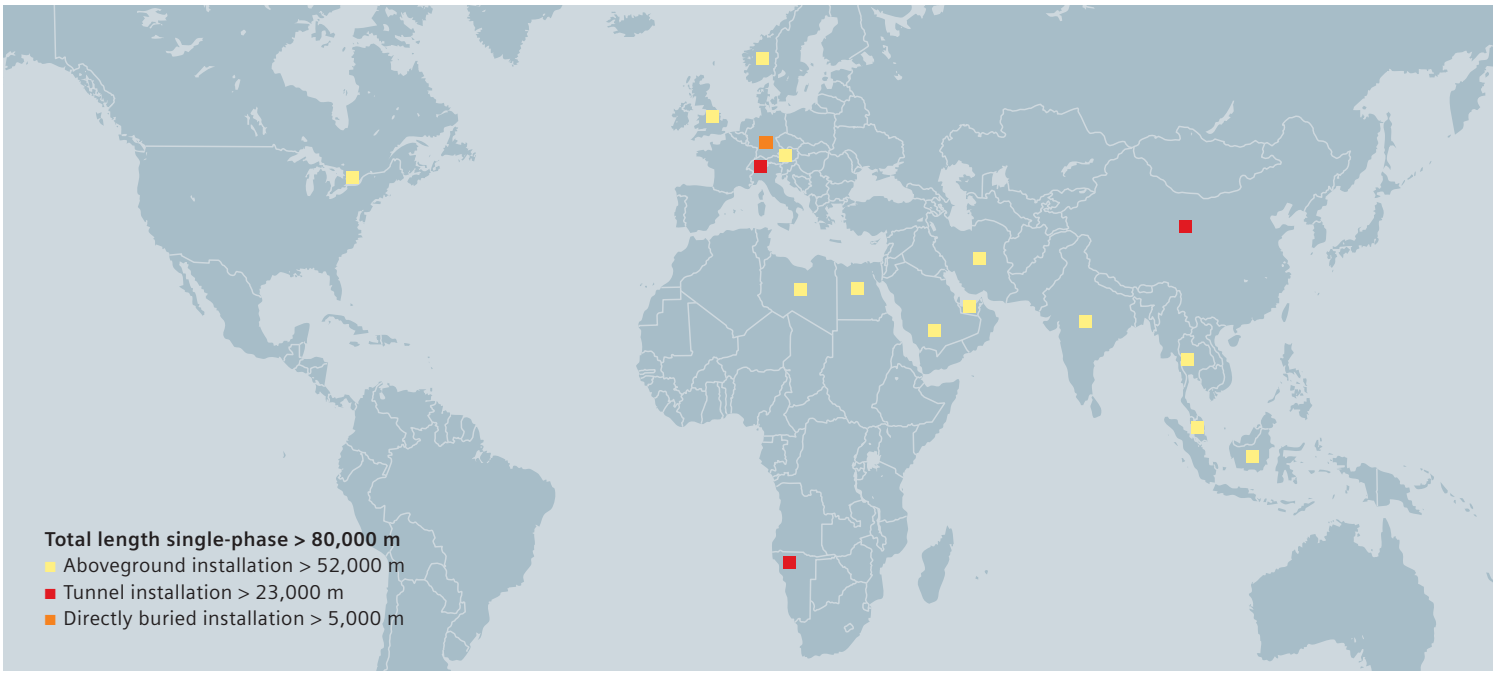


Versatility in application and laying methods

Aboveground installation
GIL installation aboveground is a trouble-free option, even for extreme environmental conditions. GIL are unaffected by high ambient temperatures, intensive solar radiation or severe atmospheric pollution (such as dust, sand or moisture). Corrosion protection is not always necessary. Particularly high transmission power can be achieved with aboveground installation.

Tunnel installation
Tunnels made up of prefabricated structural elements are another quick and easy method of GIL installation. The tunnel elements are assembled in a trench, which is then backfilled to prevent any long-term disfiguring of the local landscape. The GIL is installed once the tunnel has been completed. With this method of installation the land above the tunnel can be fully restored to agricultural use. Only a negligible amount of heat is dissipated to the soil from the GIL. The system stays accessible for easy inspection and high transmission capacity is ensured.

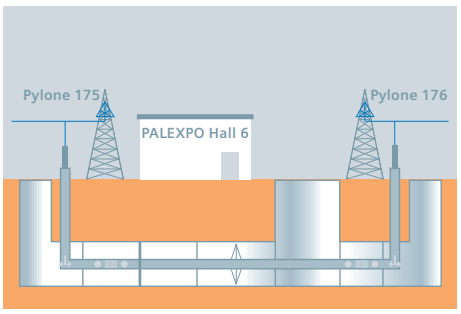
Vertical installation
Gas-insulated tubular conductors can be installed without a problem at any gradient, even vertically. This makes them a top solution especially for cavern hydropower plants, where large amounts of energy have to be transmitted from the underground machine transformer to the switchgear and overhead line on the surface. As GIL systems pose no fire risk, they can be installed in a tunnel or shaft that is accessible and can also be used for ventilation at the same time.

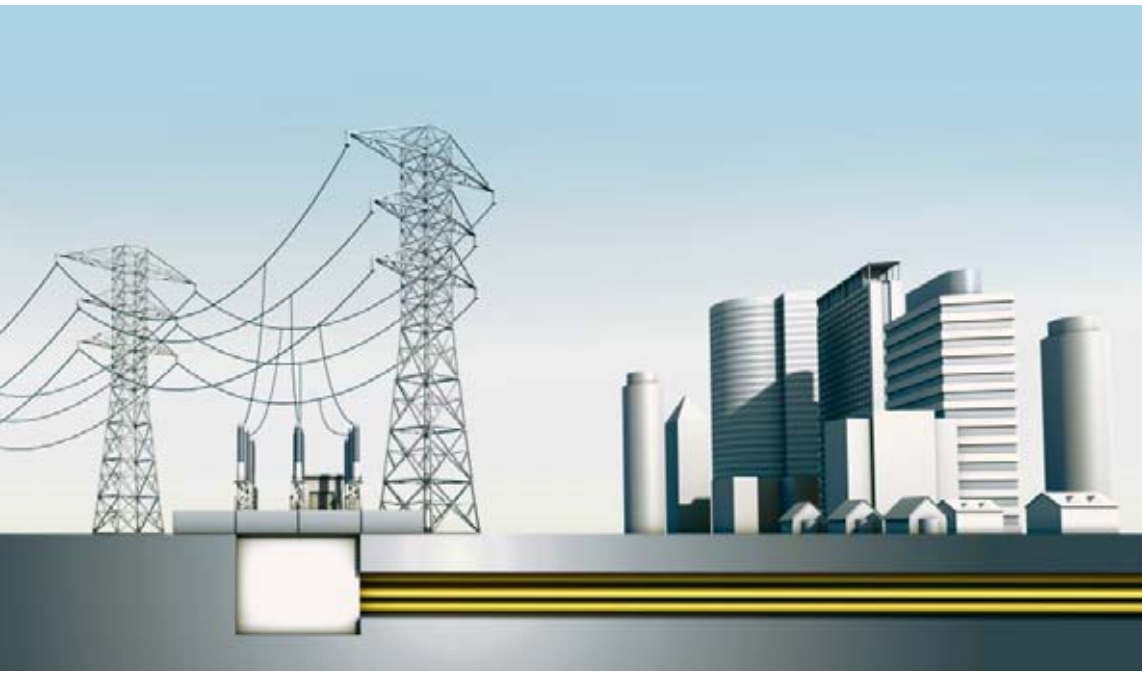


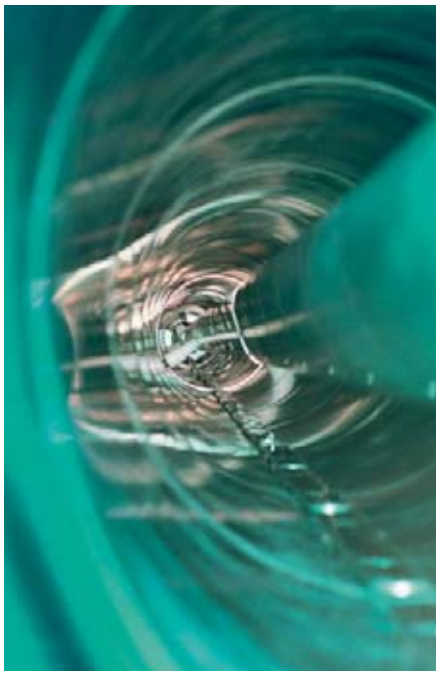
Direct burial
Siemens also offers GIL solutions designed for direct burial. These systems are coated with a continuous polyethylene layer to safeguard the corrosion-resistant aluminum alloy of the enclosure, providing protection of the buried system for >40 years. As magnetic fields are marginal in the vicinity of all Siemens GIL applications, the land can be returned to agricultural use with very minor restrictions once the system is completed.

Typical references
In the Limberg II pumped-storage power station in Kaprun, Austria, built in 2010, a GIL system was laid in a shaft with a gradient of 42°. It connects the cavern power plant with the 380 kV overhead line at an altitude of about 1,600 meters. As GIL systems pose no fire risk, the GIL tunnel is not only accessible but also used for ventilation purposes. This resulted in substantial cost reduction by eliminating the need for a second shaft in this project.

A typical example of low EMC values is the PALEXPO project in Geneva, Switzerland. A GIL system in a tunnel replaced 500 meters of a former 300 kV double overhead line which had to be moved for the raised exhibition center building. The line owner based his decision to opt for a GIL solution over a cable solution on the GIL's much better values with respect to EMC. Highly sensitive electronic equipment can now be exhibited and operated in the new hall without any danger of interference from the 300 kV connection located below it.







Coherent concept from design through operation

Minimum effort – optimum result
GIL was developed to meet a wide variety of requirements for installation and operation. A decisive factor in meeting this demand was an installation process that permits assembly of prefabricated modules at the installation site, thus allowing optimum adoption of the selected routing. This concept also has logistic advantages. All elements such as tubes, angles and special modules are lightweight and small enough to be transported by comparatively light standard trucks.

During installation a major focus is providing gastight connections for the components. To accomplish this requirement, Siemens employs a computer-controlled automatic welding process. A welding robot ensures the highest precision and reproducibility of the welding seams. The quality of each seam is verified to 100 percent with ultrasonic tests to ensure perfect gastightness and mechanical strength. As a result, no replenishment of insulation gas is needed during the entire service life of > 50 years.

GIL – Technical data	
Rated voltage	245 to 550 kV
Typical rated current (higher values on request)	up to 4,500 A
Rated short-circuit current	63 kA/3 s
Insulating gas	N_2 and SF_6 mixture
Typical system length	100 m to 100 km
Impulse withstand voltage	1,050 to 1,675 kV
Capacitance	55 nF/km
Overload capacity	up to 100% depending on design and requirements
Outer diameter	~375 to 512 mm
Weight per phase	50 kg/m

Company founder
Werner von Siemens, 1887

Challenges now and in the future

Our company founder, Werner von Siemens, had a passion for inventing trendsetting technologies and placing them into the service of mankind. Siemens GIL is very much in line with this philosophy, since its pioneering technological advantages revolutionize energy transmission with extra-high voltage and extra-high current.

Continuously growing world population and urbanization lead to a strongly increased demand for bulk power transmission at extra-high voltage, right into the heart of cities. At the same time the available space for transmission systems has been restricted more and more, and environmental requirements such as EMC and fire protection have gained increased importance. GIL fulfill these requirements perfectly.

Besides these demands in transmission, power generation is undergoing a conceptual change. As natural resources are limited, regenerative power generation systems are becoming more important. Offshore wind parks and solar power plants are being installed, providing a huge amount of energy at remote places. Consequently, transmission systems are needed that can transport bulk power with the utmost reliability and minimal losses.

The answer to these challenges is GIL. At places where overhead lines cannot be used, Siemens gas-insulated transmission lines provide numerous advantages that differentiate them from any other transmission system:

- High power ratings (transmission capacity up to 3,700 MVA per system)
- High overload capability
- Autoreclosure functionality
- Suitable for long distances (70 km and more without compensation of reactive power)
- High short-circuit withstand capability (including internal arc faults)
- Possibility of direct connection to gas-insulated switchgear (GIS) and gas-insulated arresters without cable entrance fitting
- Nonflammable; no fire risk in the event of failure
- Lowest electromagnetic field
- No aging

GIL will undoubtedly also be the backbone of the demanding transmission projects of the future – whether for the transmission of gigawatts of power from very large offshore wind farms through undersea tunnels, as is being considered for the North Sea in Europe; or for a maximally reliable connection of important power stations to outgoing lines, as for projects like Desert-Tec etc.; or for the transfer of bulk power underground right into the megacities of the future, for a continually improving quality of life for mankind.

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