Electricity supply using SF_6 technology

LIFE CYCLE ASSESSMENT

ABB

PreussenElektra Netz

RWE Energie

SIEMENS

Solvay
Fluor und Derivate

Increasing demand for electrical power and the technical capacities of SF_6

Sustainable concepts, that allow for being sparing with the environment and natural resources, are needed for ensuring the supply of electricity. Humanity needs sufficient quantities of electrical power, provided from reliable sources, in an environmentally compatible and economically viable manner. Sulfur hexafluoride (SF_6) makes a substantial contribution to all this. As an insulating and arc-quenching medium in high-voltage and medium-voltage switchgear, SF_6 has enabled constant advances in the transmission and distribution of electricity since 1960 like no other technology.

Discussions of environmental aspects

In the last few years, discussions of the use of SF_6 have extended beyond engineering circles to the political level. Until now, these discussions have almost exclusively dealt with the greenhouse effect of SF_6 emissions. For example, the signatories to the Kyoto Protocol to the „United Nations Framework Convention on Climate Change“ have undertaken to slow the increase in the greenhouse effect caused by anthropogenic emissions. Besides carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs), the measures concerned also involve sulfur hexafluoride (SF_6). Pursuant to the Kyoto Protocol, the differing greenhouse potentials of these gases are to be allowed for by means of CO_2 equivalents. Calculations based on atmospheric measurements show that the total worldwide emissions of SF_6 contribute only about 0.1 percent of the overall anthropogenic greenhouse effect. This includes both the SF_6 emissions from the major area of use in high-voltage and medium-voltage switchgear, and those from all other uses. Despite this small quantity, some people view the use of SF_6 as involving a conflict between its technological advantages and ecologically questionable aspects – especially since they often wrongly only consider the much higher greenhouse potential, weight for weight, of sulfur hexafluoride as compared to carbon dioxide. The environmental benefits resulting from the use of SF_6 in the transmission and distribution of electrical power are ignored in such a consideration.

In gas-insulated, metal-enclosed high-voltage switchgear, SF_6 is used as an insulating and arc-quenching medium.

Environmental protection measures and life cycle assessment

Aware of their responsibility, the German manufacturers and users of SF_6 switchgear – represented by their trade associations, ZVEI and VDEW – and the SF_6 producer Solvay Fluor und Derivate GmbH already in February 1997 undertook voluntarily suitable measures in the manufacture, installation, operation and maintenance of switchgear to prevent or minimize SF_6 emissions according to the state of the art. The most important measure is to reclaim and re-use used SF_6 on site. If this is not possible, the manufacturer, Solvay Fluor und Derivate GmbH, will take back the SF_6 and reprocess it to a good-as-new quality, or guarantee proper environmentally compatible disposal, if necessary. The development and implementation of these closed cycles of SF_6 use („SF_6-ReUse-Concept“) is a matter of cooperation between equipment manufacturers, power utilities, and the SF_6 producer, Solvay Fluor und Derivate GmbH. In a joint project, ABB, PreussenElektra Netz, RWE Energie, Siemens, and Solvay Fluor und Derivate GmbH have now taken a further step along the line of product responsibility: in order to overcome the one-sided view that is restricted to the material-based greenhouse potential, they have prepared a life cycle assessment. A realistic electricity supply system was completely analyzed, taking into account the criteria of primary energy consumption, area required, greenhouse potential, acidification potential, and nutrification potential. This is intended to create a basis for a well-founded environmental discussion, on the one hand, and to show the companies involved possibilities for further environmental optimization, on the other hand. The life cycle assessment was performed according to the specifications of the international standard DIN EN ISO 14040, and was followed and evaluated by an external independent expert from TÜV NORD.

Design of the life cycle assessment

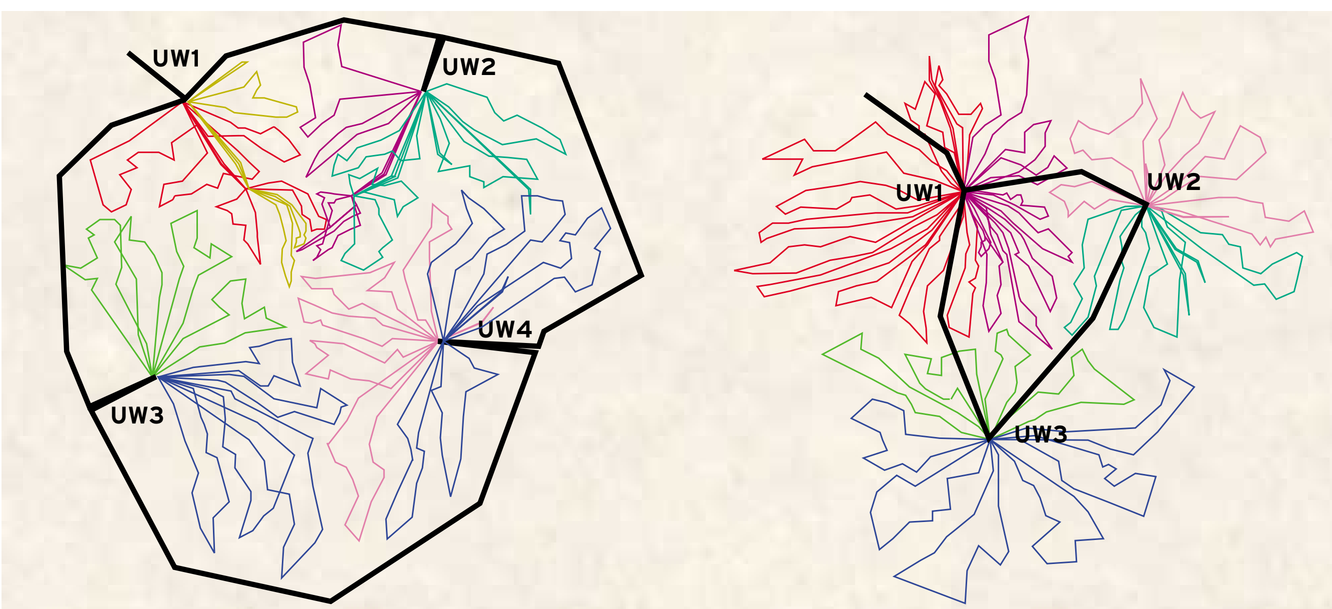
The life cycle assessment is oriented to conditions in Germany; the technologies considered reflect the present state of the art. The study compares various switchgear technologies, with and without SF_6, at the bay level and at the system level of a real urban power supply system, with respect to primary energy consumption, area required, greenhouse potential, acidification potential, and nutrification potential.

At the switchgear bay level, the following are examined:

- conventional outdoor installation without SF_6
- outdoor installation with SF_6 equipment (circuit breakers and instrument transformers)
- SF_6-insulated, metal-enclosed switchgear.

At the system level, two alternative supply models are compared, based on the given load profile of a German city about 40 km^2 large, with about 130,000 inhabitants, a peak load of 120 MW, and a consumption of 400 GWh during the first year of the period (and an annual increase in load of 1.5 percent):

- The electric power is fed into four air-insulated 110/20-kV transformer substations (AIS) on the outskirts, occupying a corresponding surface area, and distributed via the 20-kV network. The 110-kV transformer substations are connected by means of overhead lines.
- The electric power is fed via 110-kV cables into three SF_6-insulated 110/20-kV transformer substations (GIS) close to the consumers, and distributed via the 20-kV network.



Topology of the power system variants: System with AIS technology (left) and system with GIS technology (right) for a distribution voltage of 20 kV. „UW“ stands for transformer substation. The left hand illustration shows that, in the AIS version, the four air-insulated substations are located on the outskirts. In the GIS version shown on the right, the three SF_6-insulated substations are positioned within the city, and thus close to the consumers. – Thick lines represent 110-kV high-voltage overhead lines or underground cables; thin lines stand for 20-kV medium- voltage cables. While the 110-kV overhead transmission lines of the AIS version (without SF_6) circle the city, the 110-kV cables of the GIS version (with SF_6) stretch into the city, resulting in a reduction in transmission losses.

In both cases, the electric power is taken from the regional grid in a 380/110-kV transformer substation on the outskirts. Both systems are designed such that the quality of supply to the consumers is equal: differing failure probabilities of the different types of equipment are taken into account and compensated for in the planning of the power system. The design of the systems is optimized from the commercial point of view. The period considered is thirty years, the typical service life of air-insulated high-voltage switchgear, in order to be fair to all the versions of switchgear considered. SF_6-insulated switchgear can usually be used for at least ten years more.

Outdoor-type transformer substation with SF6 equipment

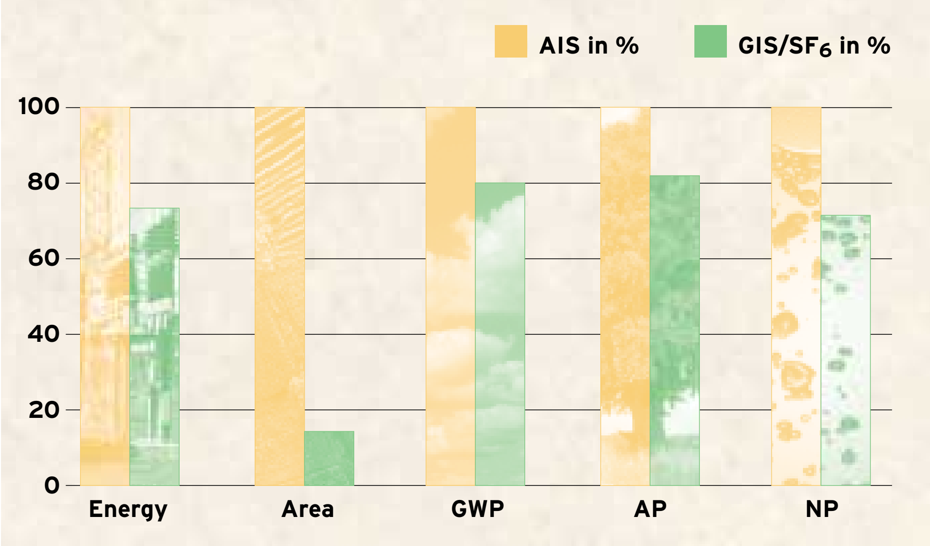
Results of the life cycle assessment

Even at the bay level, the use of SF_6 technology offers advantages for four of the five criteria of the life cycle assessment study: primary energy consumption, area required, acidification potential, and nutrification potential. Switchgear with a high utilization factor and/or the low rates of SF_6 loss achievable today provide an ecological advantage even for the greenhouse potential.

At the level that counts in the end, namely the power supply system considered, the following results are obtained: designing a power supply network with GIS technology (using SF_6) results in a reduction of about 27 percent in the primary energy consumption, of about 86 percent in the area required, of about 21 percent in the greenhouse potential (GWP), of about 21 percent in the acidification potential (AP), and of about 29 percent in the nutrification potential (NP), compared to designing the same network with AIS technology (without SF_6). The transferability of the results from this sample network has been tested in extensive scenario calculations.

The major reasons for this reduced environmental impact are: since SF_6 has considerably better insulating and quenching properties than air, substations and equipment can be made with less material and energy than in the SF_6-free AIS alternative. Furthermore, due to the compact design of the GIS components, the 110/20-kV transformer substations can be built directly at the (downtown) load centers. So the energy is transmitted at high voltage with low losses to the city centers, and distributed from there to the consumers via short medium-voltage lines.

The use of GIS switchgear in the power supply system considered reduces all the potential environmental impacts studied. The diagram shows the relative environmental impact potentials during the first year of use of the power system variant (orange bars = AIS version, green bars = GIS/SF_6 version). An increase in the system's supply capacities by about 50 percent (i.e. increased utilization of the system) results in a further reduction of about 5 percent each in the parameters primary energy consumption, greenhouse potential (GWP), acidification potential (AP), and nutrification potential (NP), due to SF_6 technology.



Conclusions

The use of SF_6 technology leads to considerable environmental advantages over the use of SF_6-free switchgear. Therefore, SF_6 technology makes sense for electric power supplies, even from the environmental viewpoint. This requires the use of GIS installations that ensure appropriately low SF_6 emissions, on the one hand, and rigorous application of the SF_6-ReUse-Concept of a closed SF_6 cycle, on the other. The technical and logistical prerequisites for this effort are already available.

It is also very clear that an environmental view limited to the greenhouse potential of a unit of weight of SF_6 cannot provide an environmental assessment of the use of SF_6 in high-voltage and medium-voltage equipment. A comprehensive consideration of entire power supply system with the help of a life cycle assessment, directed to all relevant environmental criteria, provides dependable results that are positive for SF_6 use.

The study can be ordered from the project participants

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