IMPACT OF HIGH-VOLTAGE SF_6 CIRCUIT BREAKERS ON GLOBAL WARMING - RELATIVE CONTRIBUTION OF SF_6 LOSSES

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ABSTRACT

In this paper, the contribution of SF_6 losses to the impact of high-voltage SF_6 circuit breakers on global warming is evaluated. Two air-insulated circuit breakers and two gas-insulated circuit breakers are studied over 20 years. SF_6 losses due to leakage in service, plus losses during manufacturing and commissioning, are taken into account.

For these circuit breakers, it can be seen in this study that SF_6 losses due to leakage in service or during manufacture and commissioning are not the major contribution of circuit breakers to global warming. In fact, reducing the SF_6 emissions of these circuit breakers may focus on the reduction of losses occurring during maintenance. It may be possible to reduce the global impact of circuit breakers on global warming by reducing energy losses during the life of the apparatus.

INTRODUCTION

For a few years, SF_6 has been recognized as a greenhouse gas [1]. Accordingly, many initiatives have been taken to evaluate the impact of SF_6 circuit breaker technology [2], or to reduce SF_6 release to the atmosphere.

As a contribution to the definition of an SF_6 emission reduction strategy, evaluations of the impact of high-voltage SF_6 circuit breakers on global warming are given in this publication. More specifically, the paper presents calculations that show the impact of different SF_6 loss rates, and compares them with other causes of global warming impact. These evaluations are based on more global environmental impact evaluations, presented earlier [3-4].

DESCRIPTION OF THE STUDY

Two air-insulated circuit breakers (AIS) and two gas-insulated circuit breakers (GIS) were studied. These devices, described in detail below, use SF_6 as an insulating medium.

In the environmental evaluations, most of the materials were considered, but surface treatments or coatings were not taken into account. Impact of materials was calculated considering the masses of each part. The operating mechanism was not taken into account. As it is difficult to include dismantling in the simulations made with EIME software, this phase has not been considered. The reclaiming of SF_6 at the end of life has also not been considered.

The circuit breakers were studied over 20 years. The electrical losses due to the Joule effect, based on European electricity impacts, were calculated using nominal current. Total SF_6 losses include leakage in service plus losses during manufacturing and commissioning. SF_6 losses during maintenance are not taken into account. Total SF_6 losses were considered to be equivalent to 2% vol./year as the worst case. They were considered to be equivalent to 0.5% vol./year as the best case possible, assuming that progress can be made in SF_6 handling. As a best possible value, total SF_6 losses have been taken to be equivalent to 0.25% vol./year (this value may be a reference value for sealed-for-life circuit breakers).

The environmental evaluations were made with EIME software. This software makes it possible to evaluate the impact of products on the environment. After description of the design, the software conducts a multi-dimensional evaluation of the product, based on eleven environmental indicators (raw material depletion, energy depletion, water depletion, global warming, ozone depletion, air toxicity, photochemical ozone creation, air acidification, water toxicity, water eutrophication, hazardous waste production). The calculation is done by using a data-bank of environmental impact for the most common materials and processes. It can also be used to study the impact of the different stages (manufacturing, use, transport) [5-6]. As some of the materials used in circuit breakers were not available in the EIME standard data-bank, specific modules for copper-tungsten composite, SF_6, and electrotechnical porcelain were developed. Of course, the global warming potential of SF_6 (which is 24,900 when CO_2 is 1) was taken into account in the SF_6 module.

Air-insulated circuit breaker

These circuit breakers are widely used in Europe from 72.5 to 420 kV, as well as in the Americas, up to 800 kV (Fig. 1). They are composed of a pole column containing the contact system and an operating mechanism in a metallic housing. The pole columns are mounted on a base frame and coupled with an operating mechanism. The chamber and support insulators are ceramic. The columns are filled with SF_6. The main materials used, and their weights, are given in table 1. A study of a 145 kV – 63 kA – 4000A circuit breaker (AIS 1), and a 145 kV – 31.5 kA – 3150 A (AIS 2) was performed.

Figure 1: 735 kV AIS

Figure 2: 170 kV GIS

Gas-insulated circuit breaker

These devices are used from 36 up to 800 kV, especially in highly urbanized areas. In this technology, the high-voltage parts are located in a metallic tank. The operating mechanism is still in a metallic cubicle (Fig. 2). The insulating gas is SF_6. The main materials used are given in Table 1. A study of a 145 kV – 40 kA – 3150A circuit breaker (GIS 1), and a 72.5 kV – 40 kA – 3150 A (GIS 2) was performed.

	AIS 1	AIS 2	GIS 1	GIS 2
Characteristics	145 kV – 63 kA 4000A	145 kV – 31.5 kA 3150A	145 kV – 40 kA 3150A	72.5 kV – 40 kA 3150A
Aluminum	360 kg	177 kg	380 kg	375 kg
Steel	760 kg	594 kg	220 kg	145 kg
Stainless steel	43 kg	18 kg	24 kg	20 kg
Copper	26 kg	3.5 kg	12 kg	91 kg
SF_6	10 kg	8 kg	15 kg	16 kg
EPDM	1.2 kg	4 kg	1 kg	0.8
Copper-tungsten	3 kg	0.5 kg	1.5 kg	0.4
PTFE	1.5 kg	2.8 kg	6.5 kg	2.5
Epoxy resin	4 kg	2.5 kg	23 kg	11 kg
Molecular sieve	1.7 kg	0.7 kg	1 kg	1.2 kg
Porcelain	1060 kg	670 kg	0 kg	0 kg
Total weight	2400 kg	1500 kg	670 kg	670 kg

Table 1: Materials used in different circuit breaker

RESULTS

The different contributions to the impact of circuit breakers on global warming are illustrated in the following figures. The global impact on global warming is indicated on the Y-axis, as given by the EIME software.

For AIS (Fig. 3, 4), it can be seen that, for an SF_6 loss rate of 0.5% vol./year, SF_6 loss contributions represent only about 10% of the total impact of the circuit breaker on global warming. Reducing SF_6 losses to 0.25% vol./year (even if not realistic) will change the global impact of these circuit breakers very little.

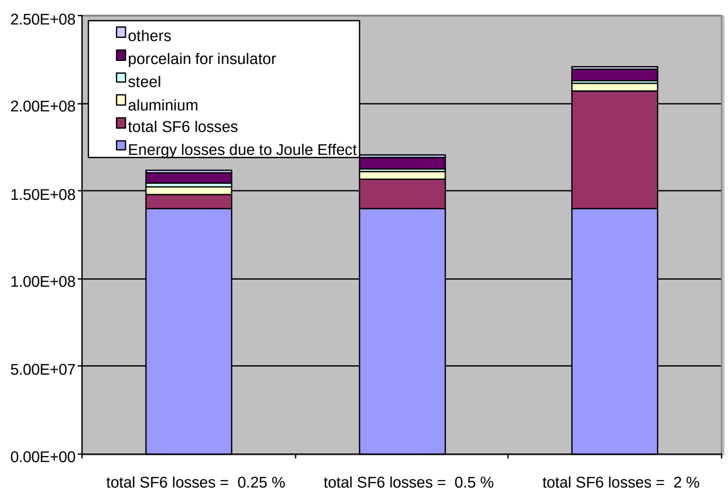

Figure 3: Relative contributions to the impact of AIS 1 on global warming

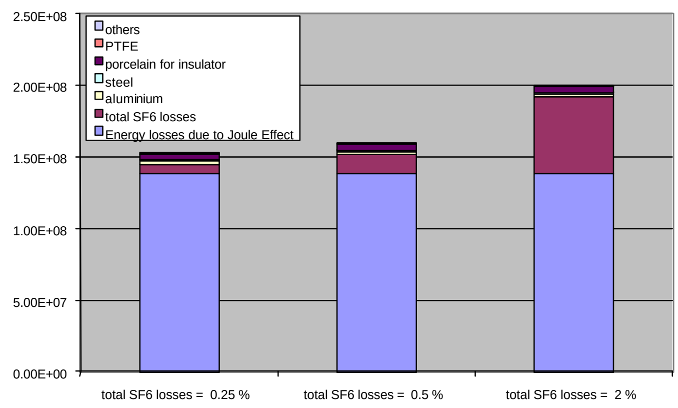

Figure 4: Relative contributions to the impact of AIS 2 on global warming

For GIS (Fig. 5, 6), it can be seen that, for an SF_6 loss rate of 2% vol./year, contributions to global warming of SF_6 losses and of energy losses due to the Joule effect are nearly equivalent. For 0.5% vol./year, SF_6 loss contributions represent about 30% of the total impact of the circuit breaker. Reducing the emissions from 0.5% vol./year to 0.25% vol./year by 50% will reduce the total impact about 15%.

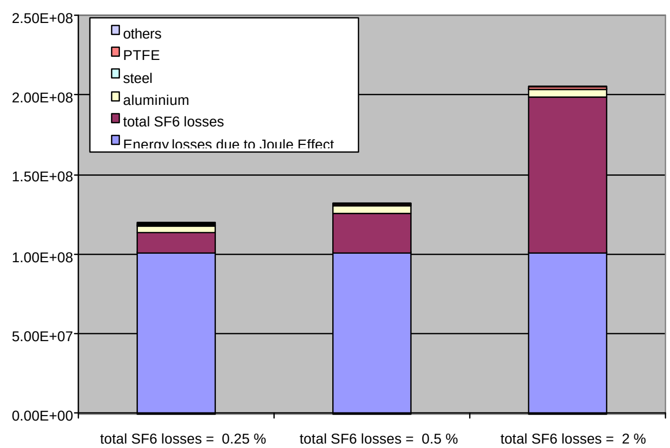

Figure 5: Relative contributions to the impact of GIS 1 on global warming

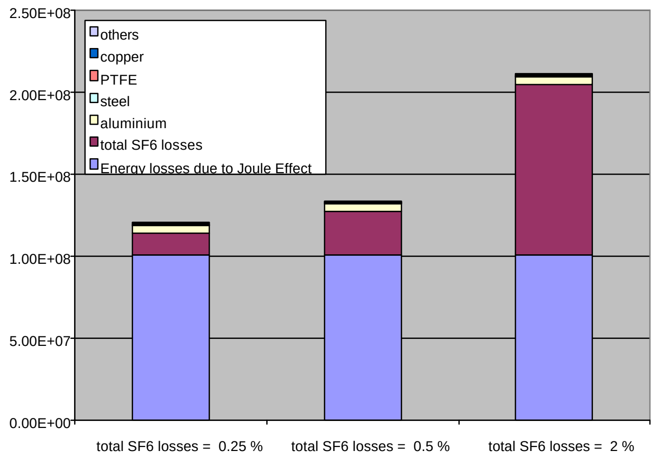

Figure 6: Relative contributions to the impact of GIS 2 on global warming

CONCLUSION

Equivalent SF_6 losses of circuit breakers of actual technology are about 1 vol./year, or 0.5% vol./year in the best cases. For these circuit breakers, we can see in this study that SF_6 losses due to leakage in service or during manufacture and commissioning are not the major contribution to global warming. In fact, for these circuit breakers, attempts to reduce SF_6 emissions may focus on the reduction of SF_6 losses during maintenance. Indeed, losses during maintenance are surely higher than 2% vol./year.

More generally, a reduction of the global impact of circuit breakers on global warming may be considered. For circuit breakers of the actual technology, reducing the emissions will help very little to achieve this goal. In fact the best way to reduce this global impact may be to reduce the energy losses during the life of the apparatus.

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