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Question PS2.2 Much development has taken place to reduce SF_6 impact on the environment from utility application for electrical insulating and interrupting equipment. What are likely to be the enduring **initiatives to prevent SF_6 gas leaks** and find a possible alternative to SF_6 for GIS applications?

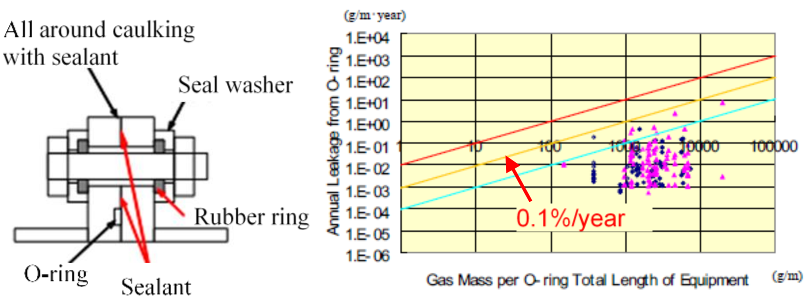
SF_6 leakage reduction from EHV-GIS by advanced gas tightness and N_2/SF_6 mixture

1. Issues of aged early generation EHV-GIS and two solutions

Gas-insulated switchgear (GIS) of especially EHV class in an early generation above 40 to 50 years old uses larger SF_6 amount than the latest GIS, and there is a concern that SF_6 leakage would increase due to deterioration of gas sealing by ageing, rust, etc. Therefore, SF_6 leakage reduction is required to minimize the environment impacts. Also, it would take a certain transition period for EHV-class GIS to fully achieve non-SF_6 equipment. For these issues the authors propose the following two solutions to reduce SF_6 leakage: advanced gas tightness with proven high gas sealing performance and SF_6 amount reduction by N_2/SF_6 mixture.

Advanced gas tightness technics

Figure 1 shows an example of structure of advanced gas tightness, which consists of O-ring, sealant and seal washers. The field data showed that SF_6 leakage rate was less than 0.1%/year after 10 to 20 years operation [3].

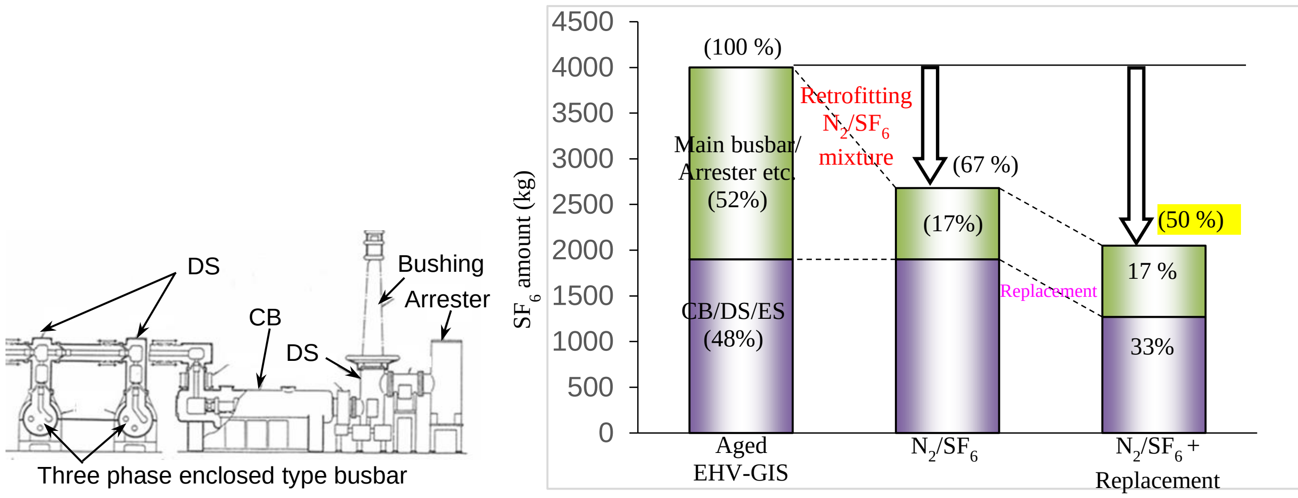


(a) Structure of flange (b) Field data of SF_6 leakage

Figure 1: Gas tightness structure and its field data [3]

SF_6 amount reduction by N_2/SF_6 mixture

Retrofit with N_2/SF_6 mixture is applicable to the passive components of EHV GIS in early generation (Figure 2 (a)) such as lightning arrester, bushing, busbar as shown in Figure 2 (b). When 25% SF_6 / 75% N_2 mixture is applied to the components, the SF_6 amount can be reduced from 52% to 17%. The filling gas pressure needs to be raised within the allowable range of the retrofitted tank strength to ensure the same dielectric performance as the original GIS. SF_6 amount can be lowered from 48% to 33%, when active components like circuit-breaker (CB), disconnector (DS), earthing switch (ES) are partially replaced with the latest downsized one of small SF_6 amount if considering their ageing. Therefore, SF_6 amount of the entire GIS can be reduced by approximately 50% by applying N_2/SF_6 mixture and replacement.



(a) Outline of typical 550 kV GIS in early generation (b) SF_6 amount reduction by N_2/SF_6 mixture and replacement

Figure 2: SF_6 amount reduction of 550 kV GIS

2. Evaluation of effects for aged early generation EHV-GIS

Current and future risk of SF_6 leakage

As a typical ageing example, a literature [1] says that SF_6 leakage rate increased to 2%/year for a 30-years old product compared to the initial rate of 0.5%/year. This drastic leakage increase was caused by rust in GIS flanges that deteriorated the gas tightness. The value corresponds to 2%/year leakage is expressed as 100% in Figure 3 (Typical ageing).

In Example A (left side), the data for the last 3 years was reported to be 1.29%/year in [2]. However, as in the above Typical ageing, there is a future risk that SF_6 leakage rate will increase by rusting and/or ageing (as in 1.29%/year to 2%/year).

In Example B (left side), when the advanced gas tightness in Figure 1 was applied, SF_6 leakage rate was less than 0.1%/year even after 10-20 years old. However, an increase of SF_6 leakage rate was confirmed after 40-50 years GIS operation even though using the advanced gas tightness, i.e. an average SF_6 leakage rate increased up to 0.3%/year referring to field data of GIS over 40 years operation in several substations of a Japanese power company.

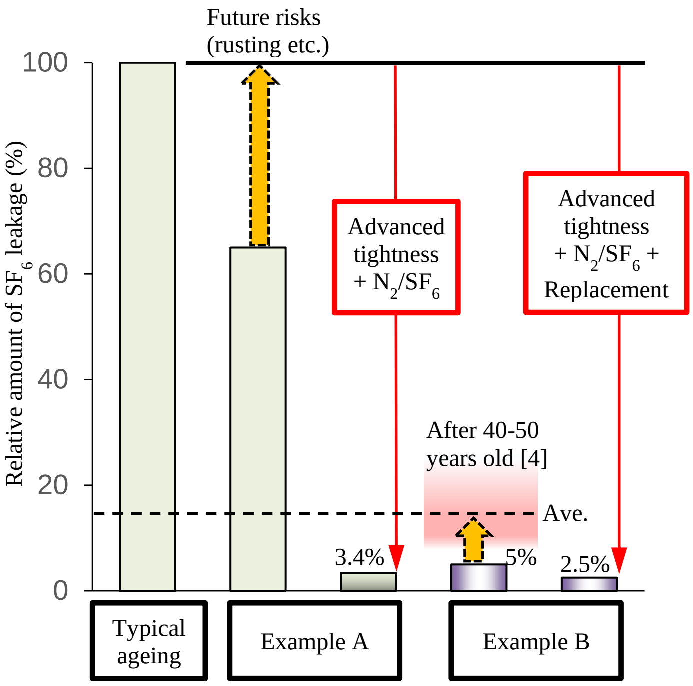


Figure 3: Effect evaluation of SF_6 leakage reduction

Effects of SF_6 leakage reduction

It will be possible to lower SF_6 leakage as follows by applying advanced tightness and N_2/SF_6 mixture as shown in each right side of Examples A and B in Figure 3.

- ✓ Example A: SF_6 leakage can be reduced to 3.4% (= 0.1/2×67/100) by improving SF_6 leakage rate (2%/year to less than 0.1%/year by advanced gas tightness) and SF_6 amount reduction (67% by N_2/SF_6, without replacement).
- ✓ Example B: SF_6 leakage can be lowered to 2.5% (= 0.1/2×50/100) by improvement of SF_6 leakage rate (ave. 0.3%/year to less than 0.1%/year by refurbishing advanced gas tightness) and SF_6 amount reduction (50% by N_2/SF_6, with replacement).

Note that these two solutions will be applicable to UHV-GIS which has large SF_6 amount. Therefore, these are considered as effective alternative solutions until non-SF_6 is fully applicable.

3. Summary

Aged EHV-GIS in an early generation has larger SF_6 amount than the latest GIS and a future risk of SF_6 leakage increase due to deterioration of gas sealing by ageing, rust, etc. Therefore, the SF_6 leakage reduction is required to minimize the environment impacts. A certain transition period would be also necessary to fully achieve non-SF_6 equipment for EHV-GIS. To solve such issues, the application of advanced gas tightness and N_2/SF_6 mixture (with replacement) to the EHV-GIS will be one of effective solutions to lower the SF_6 leakage.

Bibliography

[1] Edgar Dullni, et.al. "Reducing SF_6 emissions from electrical switchgear", CARBON MANAGEMENT, 2015

[2] Phillip Widger, et.al. "Evalluation of SF_6 Leakage from Gas Insulated Equipment on Electricity Networks in Great Britain", Energies, 2018

[3] Recycling guide of SF_6 used for power equipment, Electric Technology Research Association, Vol. 54, No. 3, 1998 (in Japanese)