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Solutions to remove SF_6 leaks and reduce HV equipment environmental footprint

Question:
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?

Inevitable SF_6-emissions
With regular improvement over the last decades, equipment manufacturers (OEMs) have substantially decreased the leakage rate of SF_6 equipment from over 3% per year to below 0.1% per year. This work has an undeniable positive impact on the SF_6 emissions and their impact on the climate, and on the maintenance of substations.

However, the current tightness is reaching a technical limit that will make every improvement very difficult. This is especially true because other factors are adding constraints in the admissible solutions, such as price, compactness, maintainability, modularity, operating temperature range, and lifetime.

A recent study of the ZVEI [1], based on data for Germany, shows that the use of SF_6 equipment, even with a maximum leakage at 0.1% per year, will not permit to extensively reduce the SF_6 emissions, with similar levels in 2030 and 2100, around 75% of 2020 emissions. The growing use of SF6 equipment in the Grid cancel in the long term the benefit of leak reduction for a net-zero objective.
Their simulations highlighted that only the replacement of SF_6 would allow to durably and significatively reduce the emissions, and therefore, contribute to the objectives fixed by the Paris Agreement.

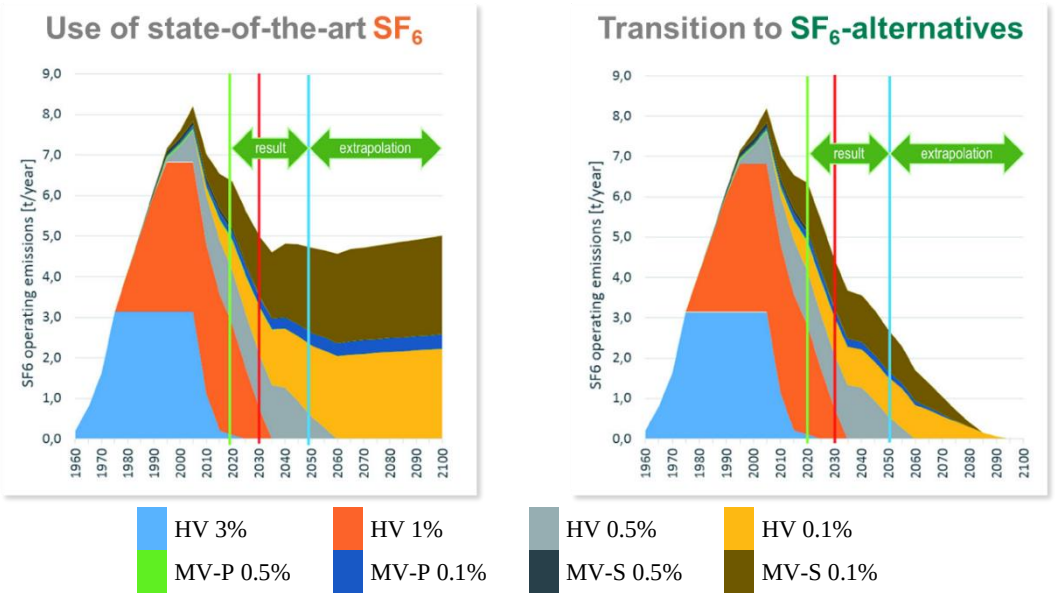

Figure 1 - ZVEI scenarios results (data from Germany)

Options to reduce SF_6 emissions
Several options exist for the HV equipment end-users to reduce SF_6 leakages.

<u>Minimizing</u>
The first option is straightforward and consist into repairing the leaks. The major challenge for the network operators is that they cannot repair nor replace equipment at an infinite rate. The solution is therefore to identify and quantify leaks. This can start by regularly reporting the pressures and losses of SF_6 in equipment in service.

Once identified, the major leaks' repairs can be prioritized, in order to have the biggest impact on both the SF_6 losses and the number of maintenances required.
It is possible to use data analysis or monitoring to facilitate the identification and quantification. Usually, data collection is an important part of the effort of repairing leaks.

The repair itself can be done either by cleaning or replacing the faulty sealing or equipment.
However, new solutions have appeared in the last decade and some non-intrusive solutions can be used. Non-intrusive solutions are usually much faster and do not require site tests. It allows users to decrease the costs and perturbations of repairs, permitting more of them.

Improve
Existing equipment may, under certain conditions, be suitable for retrofill or retrofit opportunities. Both options are mostly applicable to passive equipment, i.e., busbar, GIL, etc. They require advanced studies and long power interruptions with careful energizing procedures.
Retrofill and retrofit are usually done with C4-FN mixtures which are the only ones to get close to SF_6 in term of insulation performance. The gain is undeniable as the replacement of SF_6 is done with another gas, with GWP reduction in the range of 99%, removing all SF_6 leakage and significatively reducing CO_2-equivalent emissions.

Both solutions avoid grey energy emissions as most (or all) of the equipment is re-used. However, they suffer limitations from the enclosures (maximum pressure), minimum operating temperature (maximum C4-FN content) and design consideration (dielectric margin, sealing types, etc.).
Retrofill is certainly much more economically interesting because it requires limited work. Retrofit ensures higher performance because of the liberty of doing small modifications but results in higher costs and longer intervention times.

Retrofill and retrofit are only foreseen as solutions for recently installed equipment whose condition and remaining lifetime are synonym of long service time with the replaced gas.

Replace
According the ZVEI study, users must stop using SF_6 equipment in the long-term to reduce their CO_2-equivalent emissions. This will only be achieved by replacing SF_6 solutions by new ones.

Network operators should first evaluate their needs and, if applicable, review their requirements. Over-dimensioning a substation because of a short-circuit or nominal current rating can for example lead to bigger equipment, with high grey energy emissions (including civil work) and bigger gas volumes and leakages.

The complete CO_2 footprint of the solutions must be considered. Decision made on the basis of a Life Cycle Assessment (LCA) avoid the possible pollution's transfer linked to sole GWP considerations This implies obviously fair and reliable LCA studies and standards.

Manufacturers have demonstrated their will to replace the SF_6 range and several products from different companies are already commercially available. The coverage of most of the range is underway and solutions like "dual-gas" products exist for the users to integrate gradually the new solutions in standalone or as SF_6 substations' extensions. Dual-gas products are reassuring for the users as they offer a possible fallback to SF_6, even if very unlikely.

Conclusions
There is no way to permanently reduce SF_6 leaks. Repairs can mitigate leaks in old equipment and retrofill/retrofit can be considered for newer substations, but both solutions are only medium-term.
To reach the objectives of the Paris Agreement, the switch to SF_6-free solutions is necessary. LCA is a must to evaluate reliably the different coexisting solutions and avoid pollution transfer (grey energy).
Time is key in the action against climate change and the network must quickly adapt. SF_6-free solutions are already commercialized and will require time to fully penetrate the market. However, delayed action will require even bigger CO_2-emissions' reductions later. It is time to act, time to change.

Bibliography
[1] German Electrical and Electronic Manufacturers' Association, "Scenario for reducing SF6 operating emissions from electrical equipment through the use of alternative insulating gases," 13 07 2020. [Online].