WHITEPAPER

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Zero Emissions through State-of-the-Art SF_6 Gas Handling

Peter Pilzecker

Introduction
This article gives an overview on current international regulations, state-of-the-art SF_6 gas handling equipment and SF_6 re-use based on DILO's "zero emission" philosophy.

Pros and cons
SF_6 is a non-toxic, inert insulating and quenching gas of high dielectric strength and thermal stability and has been successfully used for more than four decades in enclosed medium and high voltage switchgear and circuit breakers.

SF_6 gas offers numerous advantages in power transmission and distribution: SF_6 insulated switchgear take up less surface area as they can be built in a compact way allowing substations even to be placed in narrowly spaced urban locations or underground. In addition to low maintenance needs and high operating reliability, gas insulated switchgear can be configured, compared to oil or air insulated electrical equipment, with higher voltages so that energy losses in T&D are kept to a minimum.

It is to be noted, however, that SF_6 is also one of the six greenhouse gases listed in the Kyoto protocol. The non-toxic, non flammable and non-corrosive SF_6 gas has a global warming potential of 22,800 times higher than that of carbon dioxide. In other words: When 1 kg of SF_6 is released into the atmosphere it has the same greenhouse effect as a petrol-driven medium sized vehicle with a total mileage of around 120,000 km (emitting around 185 g of CO_2 per km). The atmospheric lifetime of SF_6 extends over 3,200 years.

Following these facts, special attention has to be paid to sustainable and emission-free SF_6 gas handling.

Specifications of SF_6 gas

IEC 60376
This IEC standard includes the specifications for new SF_6 gas as it is supplied by the gas producers.

IEC 60480
This guideline stipulates the requirements for the recovery and recycling of used SF_6 gas.

Maintenance and end of service life are also covered by this regulation recommending procedures for checking and treatment of used SF_6 as well as specifications for SF_6 re-use in switchgear. For operation and SF_6 gas handling on site, the major parameter is gas purity stipulated by this standard.

IEC 62271-4, Chart 6, No. 4
Further to procedures for safe and environmentally friendly handling of SF_6 during installation, commissioning, operation and end-of-life disposal of HV switchgear and control gear, this directive stipulates a final vacuum in gas recovery of $\leq$ 20 mbar, a major determinant in lowering SF_6 emissions.

European legislation
In addition to IEC standards and the implemented voluntary agreements for SF_6 emission reductions in various European countries, a framework of regulations has been formalized in Europe to include some of the main best available techniques.

Regulation (EC) No. 517/2014 of the European Parliament on certain fluorinated greenhouse gases (F-Gas Regulation)
The regulation 517/2014 which repeals the EC Regulation 842/2006 from 2006 entering into force as of January 2015 states that all kind of SF_6 handling must be executed by trained and certified personnel only. This extends the requirements of the EC regulation 842/2006 concerning the recovery of SF_6 only. The complementing EU Regulation 2015/2066, which came into force on November 17, 2015, determines the minimum requirements for the certification of personnel.

Furthermore, the F-Gas regulation 517/2014 also covers subjects such as reporting and labelling of SF_6-filled components (EU Regulation 1191/2014 and 2015/2068).

All changes and supplements of the F-Gas regulation are commented in the "Explanations regarding the new F-Gas Regulation (EU) 517/2014 relating to the use of SF_6 in energy transmission and distribution" published by the ZVEI (German Electrical and Electronic Manufacturers' Association).

Mitigating SF_6 emissions

Under optimum operating conditions, SF_6 entirely remains in the transmission and distribution equipment. Acc. to CIGRE findings, most SF_6 emissions are caused by inadequate gas handling. This shortage can be prevented by appropriate training of personnel on the one hand and by using equipment of the latest generation on the other.

Here is an example of **residual gas emissions** in SF_6 recovery underlying a final vacuum of:

50 mbar: 304 g/m³
20 mbar: 120 g/m³
5 mbar: 30 g/m³
1 mbar: 6 g/m³

These data clearly show that gas recovery down to < 1 mbar is a highly appropriate provision to reduce emissions substantially. SF_6 gas emissions caused by inadequate SF_6 gas handling are avoidable since there is different state-of-the-art SF_6 gas handling equipment available, being suitable in size and performance to carry out maintenance work. Even older service carts can be refitted with suction pumps allowing to enhance gas recovery performance to < 1 mbar.

State-of-the-art SF_6 service carts

In practice, the following major user demands are encountered:

Performance

- Minimized operating and process times
- Liquifying of SF_6 gas under pressure
- Filtering of SF_6 gas (moisture and decomposition products) during recovery and filling process
- Consistent preciseness of measuring instruments
- Highest reliability even under extreme conditions

Handling and maintenance

- Easy to use (e.g. automated functions, adaptable to specific customer needs)
- Adequate safety functions to prevent faulty operation
- Maintenance friendly design

Environmental friendliness

- Minimum gas recovery < 20 mbar acc. to IEC 62271-4, Chart 6, No. 4; state-of-the-art value in SF_6 recovery: < 1 mbar
- Oil-free components in SF_6 gas circulation to prevent contamination of SF_6 gas
- Consistent gas tightness of all built-in components used on service carts
- Vacuum tight and self-closing SF_6 couplings to prevent emissions into the environment

These user demands can easily be achieved with modern devices and hermetically sealing connections on service carts and gas compartments. The DILO sealing principle prevents the loss of SF_6 gas and moisture from penetrating the SF_6 gas system.

Main functions of a SF_6 maintenance unit

State-of-the-art service carts help to minimize handling costs and enhance operating efficiency on site. Main functions of SF_6 service carts comprise: gas recovery down to < 1 mbar, filtering of solid and gaseous decomposition products during recovery and filling operations, gas storage in liquid or gaseous condition, evacuation of air and refilling of gas compartments. The entire handling is performed fully automatically with built-in safety functions to prevent maloperation. Fig. 1 shows the normal sequence of SF_6 handling on gas compartments.

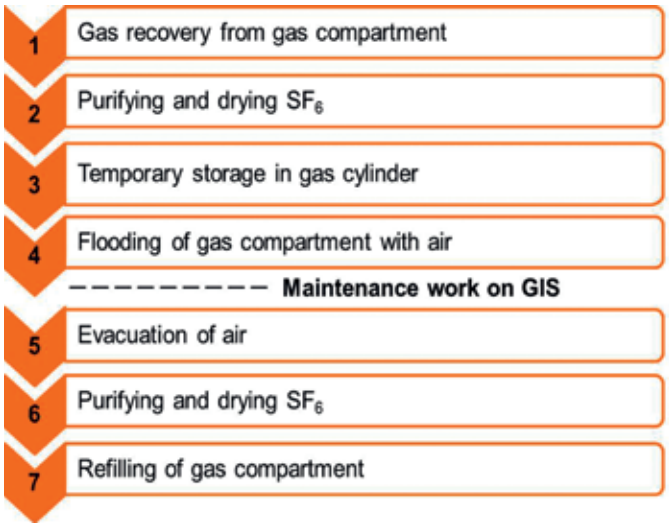

Fig. 1: Normal SF_6 handling sequence on gas insulated switchgear
Source: DILO

SF_6 re-use in a closed cycle
In practice, there are mostly two ways of SF_6 handling:
1) Direct re-use on site – the normal case
SF_6 gas on circuit breakers must always exhibit the proper gas quality as humid or toxic and corrosive decomposition products in the switchgear may severely impair insulation strength of the gas.
SF_6 gas can be used in a closed cycle meaning that it is still possible to re-use it after recovery and reclaiming from gas compartment. The prerequisite for SF_6 re-use, however, is to know the gas quality in the circuit breaker, the criteria being:

- SF_6 purity (in %)
- SF_6 humidity (dew point)
- SF_6 decomposition products based on SO_2

If measured gas quality after reclamation from the gas compartment corresponds to the limit values of IEC 60480, the SF_6 can be directly filled into the gas compartments after having registrated the handled gas quantities (SF_6 monitoring). Fig. 2 illustrates DILO's Zero Emission Concept.

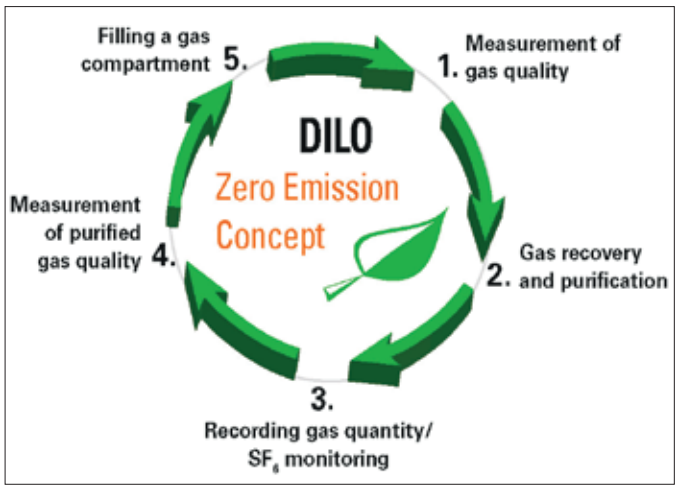

Fig. 2: DILO's Zero Emission Concept and its steps

Nowadays there are portable SF_6 Multi-Analyzers allowing to determine all three factors with one measurement, thus facilitating maintenance work considerably. There is no emission of SF_6 measuring gas as it is kept in closed circle and fed back into the gas compartment by an integrated gas return system. An exemplary measuring device is the SF_6 Multi-Analyzer from DILO.

2) SF_6 re-use after upgrade
If measuring results show that the gas quality does not correspond to IEC 60480 for used SF_6, the reclaimed SF_6 gas has to be purified either by the gas manufacturer or by appropriate equipment at the utility. For this purpose SF_6 separating plants for recycling and purification of SF_6 gas are available. These plants, which are predominantly used by utilities where large gas quantities have to be handled, achieve a purity degree fully corresponding to IEC 60480 for used gas, IEC 60376 for new gas and Chinese standard GB/T 12022/2006 for new SF_6. Recycling and purification means for the utility operator that costs for transportation, storage and expenses for new gas can be kept to a minimum.

SF_6 training & certification
Adequate training is a decisive factor in reducing emissions. EC Regulation 2015/2066 stipulates the minimum requirements for the training and certification of personnel such as security, transport regulations, general handling of SF_6, environmentally relevant questions and practical instructions.

SF_6 alternatives
Due to the high Global Warming Potential (GWP), minimization of the use of SF_6 is a target of the political landscape worldwide. Therefore several manufacturer have been looking for alternatives which are being tested at the moment. Although pilot projects with alternative gases are in operation, it will take time until the use of alternative gases for some applications can be ensured with the same reliability, safety and cost efficiency as the use of SF_6.

Summary:
When using state-of-the-art SF_6 gas handling equipment and measuring instruments and in case SF_6 gas recovery is carried out by trained personnel, SF_6 gas losses are insignificant and can be kept to an absolute minimum. Keeping emissions to nearly zero level is beneficial in regard to environmental aspects, cost savings for new gas and compliance with international regulations.

Though the use of alternative gases in power utility operations will start in the upcoming years,

the use of SF_6 as an arc quenching and insulating medium in the electrical industry will continue to be very important for the next decades and thus also the use of SF_6 handling and measuring equipment.

Company profile:
DILO is the global leader in SF_6 gas handling equipment. The company's product range covers all aspects of SF_6 gas handling equipment for maintenance of MV and HV switchgear. DILO's offering comprises a wide range of service carts with state-of-the-art technology; SF_6 measuring devices for determining SF_6 gas quality, for leak detection and indoor monitoring; automated systems for integral leak detection of GIS components; customized SF_6 gas handling plants for GIS production, supplemented by special equipment for SF_6 gas monitoring.

Author:
Peter Pilzecker, Product Manager at DILO, has been engaged in the field of SF_6 technology for more than 20 years and has a proven record of expertise in this sector. He is member of CIGRÉ and the ZVEI SF_6 Working Group.

Sources:

- International Standard IEC 60376 - Specification of technical grade sulfur hexafluoride (SF_6) for use in electrical equipment
- International Standard IEC 60480 - Guidelines for the checking and treatment of sulfur hexafluoride (SF_6) taken from electrical equipment and specification for its re-use
- International Standard IEC 62271-4 - High-voltage switchgear and controlgear, Part 4: Handling procedures for sulphur hexafluoride (SF_6) and its mixtures
- Regulation (EC) No 842/2006 of the European Parliament and of the council of 17 May 2006 on certain fluorinated greenhouse gases
- Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006
- Commission Regulation (EC) No 1191/2014 of 30 October 2014
- Commission Regulation (EC) No 2015/2068 of 17 November 2015
- Commission Regulation (EC) No 2015/2066 of 17 November 2015
- Voluntary Commitment of SF_6 Producers, Manufacturers and Users of Electrical Equipment > 1kV for Transmission and Distribution of Electric Power in the Federal Republic of Germany on SF_6 as an insulating and arc extinguishing medium, dated May 2005
- "Explanations regarding the new F-Gas Regulation (EU) 517/2014 relating to the use of SF_6 in energy transmission and distribution", ZVEI, dated January 2017

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