Sustainable Reduction of SF₆ Emission – OEMs, Users, new EU-F-Gas Regulation

2017 Workshop for SF₆ Emission Reduction Strategies
Peter Glaubitz, Siemens AG
Agenda

- Fluorinated greenhouse gases and the EU*-F-Gas-regulation
- SF₆ in CIGRÉ
- SF₆ in the IEC
- SF₆-Emission reduction
- Installed Base and the application of SF₆ in the manufacturing process
- Alternative solutions
- Conclusion

*EU = European Union
The Kyoto Protocol of the UNFCCC was the start of the EU-F-Gas-regulation and has the target to reduce greenhouse gas emissions into the atmosphere.

- SF₆ emission reduction is the focus of every (F-Gas-) regulation

1997
Kyoto Protocol

1997
TODAY

- The EU-F-Gas-regulation had to be implemented by every European member state

2006
First EU-F-Gas-regulation (EC) 842/2006

2005
German voluntary self-commitment

2008
German national Chemicals Sanction regulation

2011
Report of the EU-commission on the application, effects and adequacy of the F-Gas-regulation (EC) 842/2006

2014
Second EU-F-Gas-regulation (EC) 517/2014

- Additionally national regulations define further standards for fluorinated gases
EU-F-Gas-regulation (EG) 517/2014 involves 28 member states

- Complex, because 28 „man-made-substances“ (all F-gases) are considered
- No restrictions on the application of SF$_6$ in electrical power equipment and SF$_6$ switchgear
- Contains requirements for producers and operators of SF$_6$ electrical power equipment and implementation dates
- The new F-Gas-regulation has to be transferred into national regulations until January 1$^\text{st}$, 2017 (Article 25)
- Until July 1$^\text{st}$, 2020, the Commission shall publish a report assessing if reliable alternatives exist, which will allow the replacement of F-Gases in new MV secondary switchgear (Article 21)
- Further report on the effects of the regulation to be published in 2022 (Article 21)

Link for all regulations: [www.eur-lex.europa.eu](http://www.eur-lex.europa.eu)
Implementing Regulations for $\text{SF}_6$ electrical power equipment derived from the EU-F-Gas-regulation 517/2014

<table>
<thead>
<tr>
<th>EU-F-Gas-regulation</th>
<th>Implementing Regulations</th>
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<td>517/2014</td>
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Important articles of the EU-F-Gas-regulation 517/2014 have been detailed in implementing regulations for easier application.
EU-F-Gas-regulation 517/2014 – Prevention of emissions, leak checks and leakage detection systems

Article

- **Intentional release** shall be prohibited
- **Leakages** have to be minimized, detected leakages have to be repaired without undue delay, verify effective repair (< 1 Month)
- **Leak checks** → SF$_6$ electric power equipment is not affected provided they comply with one of the following conditions
  - Tested leakrate of less than 0.1% per year
  - Equipped with a pressure or density monitoring device
  - Or it contains less than 6kg of fluorinated greenhouse gases (per compartment)

- **Leakage detection systems** have to be installed from 1st January 2017 – for functionality reasons, in most of the cases, already implemented in the past
- **Leakage detection systems** shall be checked at least once every 6 years
- SF$_6$ electric power equipment containing less than 500ton CO$_2$e (approx. 22kg SF$_6$) do not need a leakage detection system

* Type tested
### EU-F-Gas-regulation 517/2014 – Recovery, Training and Certification

<table>
<thead>
<tr>
<th>Article</th>
<th>Description</th>
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<tbody>
<tr>
<td>3</td>
<td>Operators shall ensure that the recovery of fluorinated gases is carried out by natural persons that hold the relevant certificates provided for by Article 10.</td>
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<td>4</td>
<td>As per <strong>1st July 2017</strong> the persons carrying out the tasks below shall be trained and hold a certificate provided for by Article 10: <strong>Installation, servicing, maintenance, repair and decommissioning</strong> of SF$_6$ electric power equipment + <strong>recovery</strong> of fluorinated greenhouse gases.</td>
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<td>5</td>
<td>Only for on-site works → No certification in the factory as processes are automated (attention: maintenance of SF$_6$-handling equipment in factory).</td>
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<td>6</td>
<td>Existing certificates issued in accordance with regulation (EC) no. 842/2006 remain valid.</td>
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<td>8</td>
<td>Member States shall recognize certificates issued in another Member State (attention: language).</td>
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<td>11</td>
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<td>12</td>
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<td>19</td>
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<td>21</td>
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</table>

**Art. 8**

**Art. 10**
EU-F-Gas-regulation 517/2014 – Labelling

- Products and equipment must be labelled
- Reference to fluorinated greenhouse gases (A) and amount in kg SF$_6$ → 2015; and (B) CO$_2$e and GWP* → 2017
- Labels shall be placed on the equipment
- Information shall be included in instruction manuals and in descriptions used for advertising

* Global Warming Potential

Example of EU-label

Example of SF$_6$ quantity label
Art. 6 and 19

- Record keeping (installed amount, leaking quantities) for equipment containing SF$_6$ is **not** required as a leakage detection system (pressure or density monitoring device with remote signalling function) is installed according to Article 4.

  However operators of SF$_6$ electric power equipment should continue with their established internal documentation processes as agreed upon national self commitments.

- On 31 March of each year (introduced in 2015), the amount of bulk SF$_6$ imported into or exported from the EU has to be reported, with reference to the previous year.

  This is valid for manufacturers and operators. In addition operators have to report the amount of SF$_6$ contained in equipment imported into the EU.
CIGRÉ brochures give guidance for the environmental friendly handling of SF₆

- **2003**
  - CIGRÉ recycling guide
  - Assure long-term application of SF₆

- **2005**
  - CIGRÉ handling guide
  - Avoid SF₆ handling losses due to state-of-the-art handling

- **2010**
  - CIGRÉ tightness guide
  - Guarantee of SF₆ tightness due to state-of-the-art equipment and testing

- **2014**
  - CIGRÉ Guide for SF₆ analysis
  - SF₆ analysis for condition assessment, including dew point measurement w/o opening compartment

**TODAY**

- **2014**
  - minimization of SF₆ during routine testing
  - Guide to minimize the use of SF₆ during routine testing in the factory including site activities

**Current CIGRÉ activity regarding SF₆**

- WG B3.40 “Measuring the parameters of SF₆-Gas” (publication planned in 2017)

Link: www.e-cigre.org

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CIGRÉ SF₆-brochures

Concepts
- Keep SF₆ in a closed cycle
- Avoid any deliberate release
- Allow SF₆ re-use on-site

What shall be done?
- tightness of equipment but also of reclaimers, pipes etc.
- repair of leaks without undue delay
- long SF₆ life time

Sustainable application of SF₆
- State-of-the-art handling-equipment
- State-of-the-art SF₆ quality checks
- State-of-the-art measurement
- State-of-the-art equipment
- Best available processes

→ recover all SF₆ (0 mbar/psig*)
→ gas collecting capability
→ clear parameters
→ extended maintenance intervals
→ trained and certified service staff for SF₆ handling

→ Many CIGRÉ brochures have been transferred into Standards and regulations
→ CIGRÉ “SF₆ Green Book” planned

* 1 mbar = 0.0145 psig
The CIGRÉ ELECTRA* Position Paper…

- Published in the ELECTRA magazine no. 274, in June 2014

…gives a general overview of SF₆ and its application in the electrical industry

* Monthly magazine of CIGRÉ
IEC and the application and handling of sulfur hexafluoride (SF$_6$) in high-voltage switchgear and controlgear

**Focus on SF$_6$ Quality**

1995
IEC 61634
Use and handling of sulfur hexafluoride (SF$_6$) in high-voltage switchgear and controlgear

Was issued considering Health and Safety aspects

2005
IEC 60376
Specification of technical grade SF$_6$ for use in electrical equipment

2013
IEC 62271-4
Handling procedures for SF$_6$ and its mixtures

Replaced the first edition of IEC/TR 62271-303

**Focus on avoiding emissions**

1995
IEC 61634
Use and handling of sulfur hexafluoride (SF$_6$) in high-voltage switchgear and controlgear

2004
IEC 60480
Guidelines for the checking and treatment of SF$_6$ taken from electrical equipment and specification for its re-use

2008
IEC/TR 62271-303
Use and handling of sulphur hexafluoride (SF$_6$)

Major revision of the former IEC 61634, includes sections of the CIGRÉ handling guide no. 276 issued in 2005

**TODAY**

2008
IEC/TR 62271-303
Use and handling of sulphur hexafluoride (SF$_6$)

Major revision of the former IEC 61634, includes sections of the CIGRÉ handling guide no. 276 issued in 2005

Focus on SF$_6$ Quality
Which Measures have been implemented by Operators in order to reduce emissions?

What is SF$_6$ emission?

- Leakage losses
- Handling losses

Leakage losses can be avoided by...

- Gas-tight equipment
- SF$_6$ leak detection systems
- Immediate repair of leaks
- Replacement of electric power equipment, even before end of lifetime

Handling losses can be avoided by...

- Trained personal
- State-of-the-art handling- and measurement equipment
- Long maintenance intervals to reduce openings
The finally achieved emission rate for Switzerland of 0.12% seems to be very close to the possible optimum.

All known measures have been implemented including the replacement of leaking equipment and controlled pressure systems.
Installed base and emission of SF$_6$ in electric power equipment in Germany

- Compared to Switzerland the SF$_6$-emission can still be reduced
- The biggest lever seems to be the replacement of 1$^{\text{st}}$ generation controlled pressure systems (high leakage rates)
Development of arc quenching technologies

- Air-Magnetic US, UK
- Oil
- SF₆-Puffer Type
- SF₆-Selfcompression
- Vacuum
- SF₆-double pressure
- Air pressure

Bulk- and Minimum-Oil CBs up to 145 kV, leading technology until the 1970’s

Air-blast CBs 800/1200 kV (10/12 interrupters) and Oil CBs (245/420 kV) until the 1980’s

SF₆ puffer CBs (245 kV 40 kA / 300 kV 50 kA single-break) from 1980

420/550 kV 63 kA single-break and 800/1100/1200 kV double-break per pole from mid 1990’s

Options: other F-Gases

Source: Taskforce Siemens
Gas Insulated Switchgear: Significant reduction of Global Warming Potential with SF$_6$-Technology, further reduction with Vacuum-Technology achieved

Model calculation for 145 kV GIS rated voltage class

<table>
<thead>
<tr>
<th>Year</th>
<th>1970</th>
<th>2006</th>
<th>2016</th>
</tr>
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<tbody>
<tr>
<td>kg CO$_2$e.</td>
<td>Closed pressure system</td>
<td>1st generation</td>
<td>state-of-the-art</td>
</tr>
<tr>
<td>Operation (SF6 losses)</td>
<td>Operation (Energy losses)</td>
<td>Transport</td>
<td>Manufacturing</td>
</tr>
</tbody>
</table>

94% GWP-reduction with SF$_6$:
- Very low leakage rate
- Reduction of gas volume
- Shorter sealing length
- Design optimization

97% GWP-reduction with alternative gas solutions
- No emissions of F-gas
- High recycling rates
- Maintenance-free operation

Boundary conditions:
145 kV GIS „Old“: lifetime 40 years; SF$_6$: 180 kg, 3% leakage rate in operation, maintenance not included
145 kV GIS „state-of-the-art“: Lifetime 50 years; SF$_6$ 83 kg, 0.1% leakage rate in operation;
145 kV GIS „Alternative“: 15 kg CleanAir, one maintenance interval after 25 years

How can an alternative solution look like?
Switching-Technology – Which benefit offers the Vacuum Switching-Technology?

- Excellent arc quenching capability and proven technology in Medium-Voltage for many decades
- Excellent at low ambient temperature
- High number of C-O operations

- 5 Vacuum Live-Tank Circuit Breaker 72.5 kV in operation since 2010

Vacuum-Circuit Breakers show no discrepancies in their performance in relation to SF$_6$-Circuit Breakers

Insulating Medium 100% N$_2$
Alternative Gas Solution
Clean-Air Switchgear

72.5 kV Clean-Air application for Windtower

145 kV Clean-Air GIS

- Vacuum tubes for Circuit Breaker switching
- Clean-Air insulation $\rightarrow$ 80% N$_2$ and 20% O$_2$
- No Global Warming Potential (GWP) = 0
- Low boiling point and no liquidation at low temperatures
- Known and proven material compatibility
- Low requirements for transportation, installation, operation, documentation and recycling
- C-Gas-free $\rightarrow$ without risk of Carbon by-products in switching and insulating gas compartments
- The F-Gas-regulation does not apply to vacuum/Clean-Air electric power equipment, which reduces extensive requirements
Conclusion

To avoid SF$_6$ emission …

- All known sustainable measures have to be implemented, especially
  - Replacement of equipment and controlled pressure systems which cannot be tightened
  - Gas handling only by certified staff
- SF$_6$ emission can be reduced to 0.1% based on the installed SF$_6$ inventory, further reduction is utmost challenging
- SF$_6$ respectively F-Gas replacement solutions are under investigation – first pilot projects in place
Contact

Thank you for your attention

Peter Glaubitz
Chief Technology Officer and Principal Expert GIS Technologies
Siemens AG/ EM HP GIS CTO
Freyeslebenstraße 1
91058 Erlangen (GER)
Phone: +49 9131 735010
Mobile: +49 152 2262 4064
E-mail: peter.glaubitz@siemens.com

siemens.com