Study Committee B3

Substations and Electrical Installations

Paper ID_B3-10736

Management of SF_6 gas leakage and technical guidelines on application of substation equipment using SF_6 alternative gases in Japan

K. Nakamura *1, S. Tsukao *1, T. Nishioka *2, K. Taketa *2, T. Uchii *4, H. Hama *5
*1: TEPCO Power Grid, Inc. *2: Chubu Electric Power Grid Co., Inc. *3: Kansai Transmission and Distribution, Inc.
*4: Toshiba Energy Systems & Solutions Co. *5 Mitsubishi Electric Co.

Motivation

- SF_6 gas is used in GIS and other substation equipment around the world. Recently SF_6 alternative solutions for switchgear have been widely discussed since SF_6 has an extremely high GWP.
- SF_6 was designated as one of the greenhouse gases to be reduced at COP 3 held in Kyoto, Japan in 1997
- In response, industries using SF_6, such as electricity T&D, have strictly controlled and curbed the amount of SF_6 released into the atmosphere.

Method /Approach

- Introduction of current status of SF_6 gas leakage management from substation equipment in Japan.
- Establishment of an "SF_6 Alternative Gas Study Group" composed of experts from all electric power utilities, major manufactures and academia in Japan. The purpose was to develop guidelines for the introduction of SF_6 alternative technologies. Namely, the "Seven Requirements for SF_6 Gas Alternative Technology".

Management and reduction of SF_6 gas emissions in Japan

- Following the designation of SF_6 gas as a GHG at the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3) in 1997, the relevant industries, including electric utilities, electrical equipment manufacturers and gas manufacturers, formulated the SF_6 Gas Handling Standard for Electricity (in 1998).
- The Federation of Electric Power Companies of Japan (FEPC) and the Japan Electrical Manufacturers' Association (JEMA) formulated a Voluntary Action Plan for SF_6 gas emission reduction, setting voluntary reduction targets of less than 3% for emissions during inspection and less than 1% for emissions during disposal. (in 1998)
- To achieve the target, Japanese companies dealing with SF_6 gas are engaged in the following three activities.
  -Preventing leaks by ensuring that the gas is collected during equipment inspections.
  -Establishing methods for recovery and re-use from waste equipment.
  -Strengthening the SF_6 gas management system by using a control ledger.

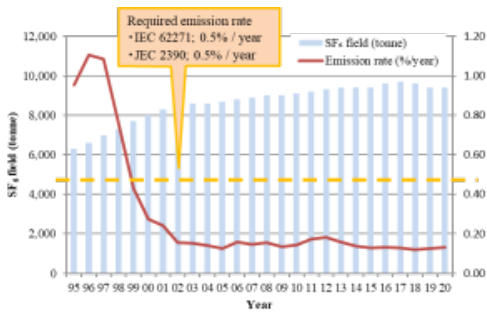


Figure 1 Quantity of SF_6 gas inventory and emissions from electrical equipment in Japan

Table Ⅰ SF_6 Gas Handling Standard in Japan for Electric Power

Item	Standard value	Remarks
Natural leakage rate from equipment	0,1% yearly	According to field measurement data of gas leakage
Final pressure for evacuation	【Manufacturing/ Installing/ Inspecting】 - 0,015 MPa abs or less 【Decommissioning】 - 0,005 MPa abs or less	In consideration of the balance between equipment outage and SF_6 evacuation time
Standard for gas quality	【Purity】 - more than 97% 【Moisture level】 - interrupting current; 150 ppm vol or less - not interrupting current; 500 ppm vol or less 【Decomposed gas】 - not detected with indicator tube	【Purity】 Level that does not affect the interrupting performance 【Moisture】 Level that does not affect creepage withstand voltage of insulation

Study Committee B3

Substations and Electrical Installations

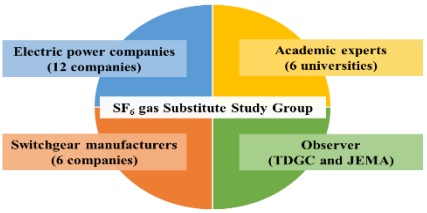
Paper ID_B3-10736

Management of SF_6 gas leakage and technical guidelines on application of substation equipment using SF_6 alternative gases in Japan

continued

Establishment of SF_6 Alternative gas Study Group (in 2016)

- SF_6 Alternative gas Study Group (The study group) was established composed of experts from all electric power utilities (12), major switchgear manufactures (6), academia (6) and observers (TDGC* and JEMA). The group developed a guideline for the introduction of SF_6 alternative technologies called the, "Seven Requirements for SF_6 Gas Alternative Technology".



* TDGC: Transmission and Distribution Grid Council in Japan

Figure2 Structure of the SF_6 Alternative Gas Study Group

Major activities of the Study Group

- In order to appropriately promote the development of SF_6 alternative equipment, it is necessary to internationally communicate the Japanese view:
  - ✓ on the future handling of SF_6 gas,
  - ✓ on the development of equipment using SF_6 alternative technologies.
- The study group has developed the so called 'Seven requirements' as a guideline for the introduction of SF_6 gas alternative technologies.
- The study group identified EHS, Service condition, Stable supply and Gas handling as the highest priorities.
- The philosophies of the 'Seven requirements' are consistent with the various position papers that have been published mainly in Europe.
- It is important to have discussions and to reach a common understanding of the 'Seven requirements' through international communities such as CIGRE.

Details of Seven requirements

1. Environment Health Safety (EHS) : Impact on human health and safety and therefore the environment are the most important requirements.
2. Service Condition : Complying with full range of temperature between -20°C and +40°C to allow outdoor installation.
3. Stable Supply: Desirable to have more than one supplier to avoid a monopoly. In addition, it is important to secure a manufacturing base located domestically in order to avoid material depletion, to maintain manufacturing technology, and to enable easy access and procurement.
4. Gas Handling: Solutions enables simplified gas handling. Also, the gas mixture ratio shall be correctly controlled and adjustable for long-term use and multiple current switching / interruptions.
5. Life Cycle Cost: Reasonable life cycle cost in order to proceed with the replacement of SF_6 equipment within a limited budget.
6. Footprint: The ability to meet spatial limitations imposed by the replacement of ageing SF_6 equipment in substations.
7. Voltage Coverage: Desirable to support up to 500 kV voltage class in the future (the maximum working voltage of the transmission system in Japan).

Table Ⅱ "Seven requirements for SF_6 alternative gas technology in Japan"

No.	Category	Requirement
1	**EHS**	Especially, toxicity of decomposition gas and decomposition
2	**Service Condition**	Normal use conditions specified in the standard
3	**Stable Supply**	Stable supply of alternative gases is possible in the future. It is desirable that gas can be supplied by multiple suppliers
4	**Gas Handling**	Simple handling of SF_6 alternative gas
5	Life Cycle Cost	Life cycle cost is equivalent or reasonable to SF_6 gas equipment
6	Footprint	Replacement in locations where installation space is limited
7	Voltage Coverage	Support up to the maximum operating voltage of 500 kV-63 kA

Study Committee B3

Substations and Electrical Installations

Paper ID_B3-10736

Management of SF_6 gas leakage and technical guidelines on application of substation equipment using SF_6 alternative gases in Japan

continued

Workshops and Symposia

- An open workshop organized by the Study Group and a symposium organized by the Institute of Electrical Engineers of Japan (IEEJ) have been held.
- IEC 62271-4, Handling procedures for gases for insulation and/or switching, is presented at the symposium. The safety factors of alternative gases based on occupational exposure limits-time-weighted average (OEL-TWA) values are introduced as a safety evaluation in case of gas leakage, which attracted much attention.

Development of SF_6 alternative gas technologies and JEMA roadmap

- JEMA (Japan Electrical Manufacturers' Association) is an industrial association that covers T&D fields. "The SF_6 Alternative Technology Task Force" was established in August 2021, composed of Japanese 7 MV/HV switchgear manufacturers; namely, Toshiba ESS, Mitsubishi Electric, Hitachi, Meidensha, Fuji Electric, Nisshin Electric, Takaoka-Toko.
- The Task Force developed a roadmap of non-SF_6 switchgear release as a summary of a questionnaire-based survey to the 7 manufacturers, according to which, as Figure 3 shows, that e.g. 300 kV GIS will be available from 2026 through 2031 by multiple manufacturers.

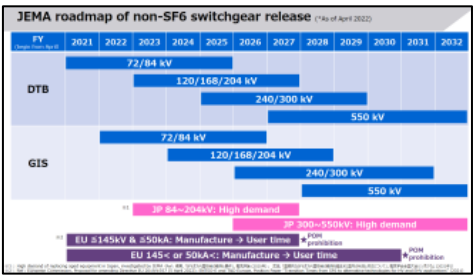
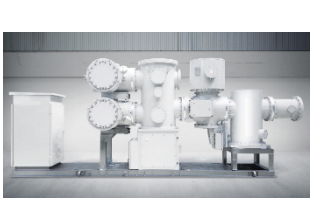


Figure 3 JEMA roadmap for Alternative gas Switchgear in Japan
URL: <https://www.jema-net.or.jp/English/pis/sf6roadmap.html>



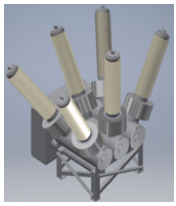
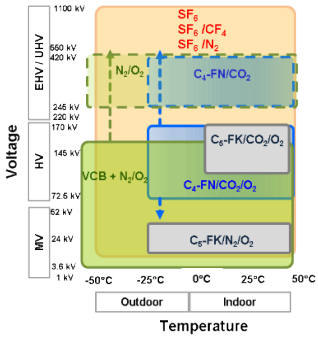


Figure 4 72/84 kV- 31,5 kA SF_6-free GIS with VCB and 145kV-40kA Dead tank VCB (with synthetic air insulation)

Future development with SF_6 alternative gas technologies

- There is currently no gas that is equivalent to SF_6 in terms of safety, reliability, economy, and compatibility while eliminating environmental risks.
- VCB + natural-origin gases would be currently evaluated to be the most promising in the area of the high voltage (HV) class and lower.
- On the other hand, no effective solution has been found yet in the range of extra high voltage (EHV) and above.



- Dashed line area of C_4-FN/CO_2: 420 kV GIL, 245 kV Instrument transformers,
- Dashed line area of N_2/O_2: 420 kV and 245 kV Instrument transformers,
- Solid line area of the others: GIS including switching components like circuit-breakers, disconnectors and earthing switches,
- Dashed line with arrow: Future perspective.

Figure 5 Overview of current status and future perspective of applications of SF_6 alternatives

Conclusions

- It is important and indispensable to continue to make thorough efforts to minimize atmospheric SF_6 emissions.
- Japanese electric power companies, equipment manufacturers, and academic experts have been working and continue together on the research and development of alternative technologies to SF_6 gas.
- The cost of the equipment using SF_6 alternative gas technology is expected to increase compared to the equipment using SF_6 gas. More specific evaluation methods, standards, and indicators are needed.
- It is important to share the basic data of SF_6 alternative gases such as switching characteristics and toxicity evaluation throughout the CIGRE community.