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QUESTION N° : PS2.2

Q 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?**

Introduction policy of SF_6 gas alternative technology considering the current evaluation

1. Introduction

Currently, SF_6 gas is used in gas insulated switchgear (GIS) and other equipment to insulate the equipment and interrupt the current, but SF_6 alternative gases are being mainly discussed in Europe from the viewpoint of preventing global warming since SF_6 gas has a high global warming potential (100 year GWP) of 25200. In 2015, the United Nations General Assembly adopted 17 Sustainable Development Goals (SDG's) as international goals for the period up to 2030, and efforts are being made around the world to achieve the Paris Agreement target, 80% reduction in CO_2 emissions.

In Japan, based on the development roadmap of SF_6 alternative gas switchgear as shown in Figure 1 [1], discussions have started among the Transmission and Distribution Grid Council (TDGC) and the Japan Electrical Manufacturer's Association (JEMA) members. The roadmap is proposed by JEMA which represents electric power equipment manufacturers.

In view of the possibility of a change in the domestic rate system and procurement system, alternative gas solutions are being studied and are introduced in this paper.

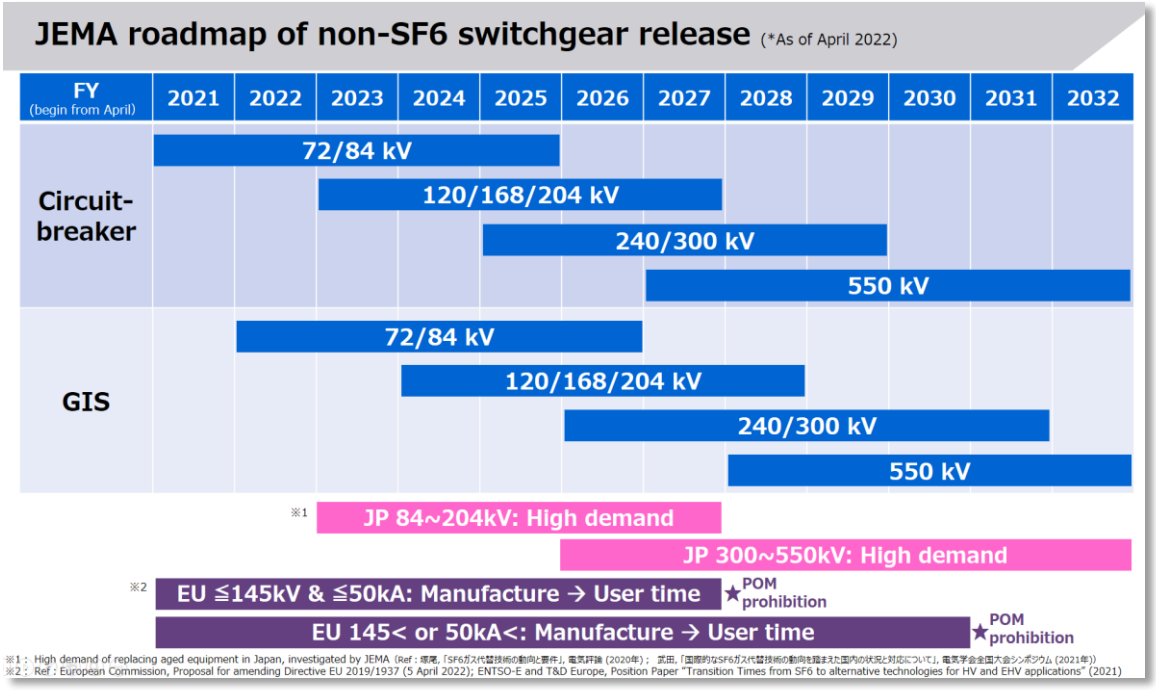


Figure1 : The JEMA roadmap of non-SF_6 switchgear development [1]

2. Current evaluation of SF_6-alternative solutions within TEPCO PG

Each solution was evaluated based on the "Seven requirements" from Japan [2], as shown in Table 1. As a result of the evaluation, from the viewpoint of accountability to stakeholders, the evaluation of environmental health and safety (EHS) and especially its toxicity, was our top

priority. The occupational exposure limit using time-weighted average (TWA) values are shown in Table 2. Sufficient tests have been conducted to comply with REACH regulations and commercial limits as shown in Table 3. PFAS (Endocrine Disruptors) [3] evaluations are ongoing.

In addition, the evaluation was carried out taking into consideration the current situation: The acute inhalation toxicity of C5-FK and C4-FN gas mixtures has been verified by OECD 403 to be equivalent to SF_6 gas, but the toxicity of arced by-products has not been sufficiently verified (evaluated only for 145 kV class switchgear). It will take a long duration (around 10 years or so) to verify the toxicity of new SF_6 free gas. Verifying the toxicity of arced by-products needs short-circuit generator facility, high-voltage circuit breakers, many short circuit tests, collecting the by-products, and analysis of the toxicity. It will cost a lot and need 3rd party verification. Therefore, for the time being, IEC ACTAD recommended to SMB that IEC TC 10 and TC 17 prepare and operate guidelines to reduce human (animal) exposure to arced by-products of fluorinated gas mixtures [4].

Table 1 : Evaluation of various gases against the "Seven requirements" guidelines

No.	Category	F-gas			Natural origin gas	
		SF_6	C4-FN	C5-FK	N_2/O_2 (synthetic air)	CO_2/O
1	**EHS**; GWP/TWA※	**25200** / 1000 ppm	2100 / **65 ppm**	1 / **225 ppm**	0 / infinite	1 / 5000 ppm
2	**Service condition**; liquefaction temperature	> -20 ℃	> -25 ℃	> 5 ℃	> -183 ℃	> -78.5 ℃
3	**Stable supply**	multivendor	single-vendor	single-vendor	multivendor	multivendor
4	**Gas handling**; mixture and control	single-gas	mixed-gas	mixed-gas	natural-gas	mixed-gas
5	**Life cycle cost**	present standard	up	up	up	up
6	**Footprint**	present standard	same	same	up	up
7	**Voltage coverage**	present standard	same	same	down	down

Table 2 : Alternative gas candidates and TWA※1 values

Evaluation gas	TWA values (ppm)
N_2/O_2 (synthetic air)	∞ (infinite)
CO_2	5000
SF_6	1000
C4-FN	65
C5-FK	225

※1) **TWA : Time-Weighted averages**

8 hours/day, 52 weeks/year, 30 years of service with acceptable health exposure limits for workers (**lower values are more dangerous**)

Table 3 : Number of test items required for alternative gases on toxicity of REACH regulations※2

Volume bands	Number of test items※2
> 1 ton	8
> 10 tons	18
> 100 tons	23
> 1000 tons	30

C4-FN

Manufacturer's Opinion
If the amount handled increases, additional tests can be conducted.

SF_6

※2) **Toxicological information in the REACH regulations includes test items** such as skin corrosion/irritation, mutagenicity, acute toxixity, reproductive toxicity, toxicokinstics and carcinogenicity etc.

In addition to safety, the current evaluation results support a solution based on natural origin gases. Such solutions are expected to be commercialized in the coming years based on JEMA's development roadmap in Figure 1. Field introduction will be carried out as soon as equipment development is completed.

Specifically, a gas-insulated switchgear equipped with a 72 kV synthetic air-insulated vacuum circuit breaker will be installed at the Fuchu substation in December 2022. (In February 2024, additional lines are planned at the same substation).
Although it is larger than the latest SF_6 gas insulated equipment, the GIS to be introduced this year is about the same size as the aging GIS to be replaced, therefore the foundation can be reused.

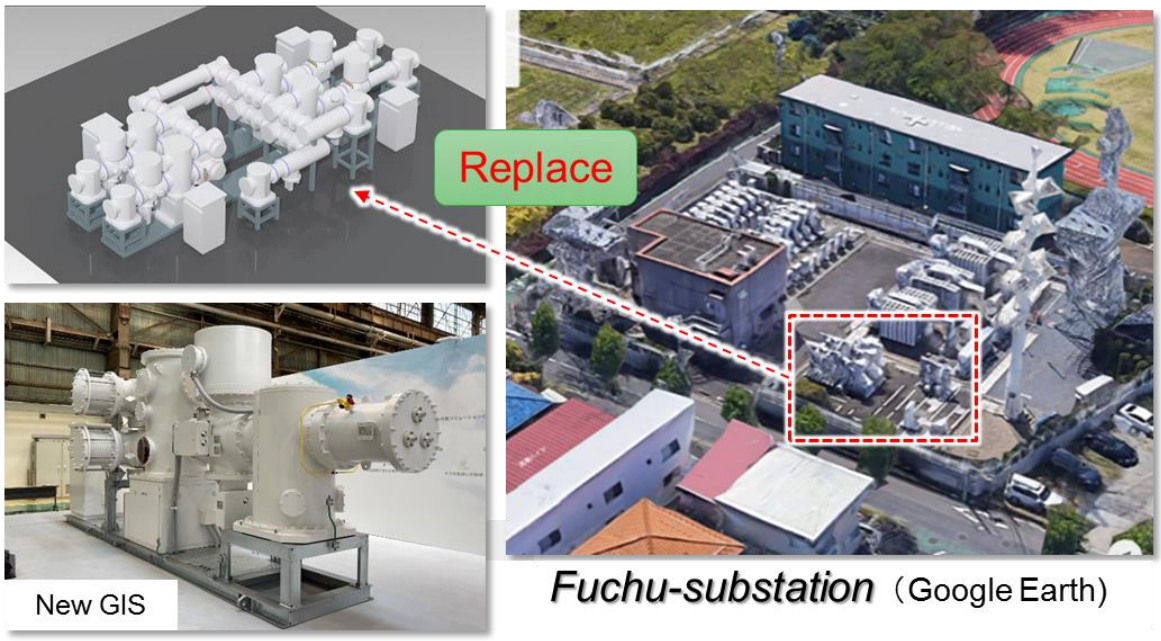
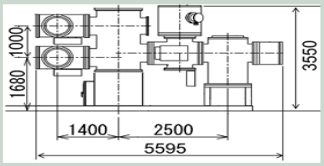
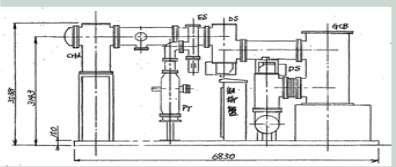


Figure 2 : Plans for introduction into the field

Tabel 4 : Physical comparison of new 72 kV alternative gas GIS with existing GIS

	New GIS	Existing GIS
Overview		
Bay length	5595 mm(82%)	6850 mm(100%)
Bay height	3550 mm(100%)	3538 mm(100%)
Bay width	1600 mm(80%)	2000 mm(100%)
Weight per bay	11.6 tons(97%)	12.0 tons(100%)

3. Conclusion and future work

At this time and as a result of the evaluation of alternative gas solutions at TEPCO PG, we have supported natural origin gas solutions and introduced the field launch of a 72 kV synthetic air-insulated GIS in December 2022. The decision considers both the seven requirements for SF_6-alternatives and the development trends of domestic manufacturers.
Japan regulator will introduce a new tolling system (revenue cap system) for regulating T&D energy network businesses in FY2023 that includes items such as "consideration for the environment". Therefore, we will continue to build a comprehensive evaluation system that uses environmental incentives such as measures that contribute to carbon neutrality and efforts to reduce greenhouse gas emissions as indicators.

Bibliography

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[4] IEC SMB/7668/R, 2022-08-05