RE: August 15, 2019 Public Workshop to Discuss Possible Amendments to the Sulfur Hexafluoride ($SF_6$) Gas Insulated Switchgear Regulation

TO: CARB Staff

Thank you for publishing the recent proposed draft amendments to California SF6 gas insulation switchgear regulation and for hosting the August 15 public workshop in Sacramento. We appreciate the opportunity to review and comment in an open forum during the regulation development process.

General Electric has been investing in research for SF6-free alternative technologies for more than ten years and has industrialized a solution under the brand name of $g^3$ (Green Gas for Grid) which is a mixture of 3M's Novec $4710_{TM,}$ $CO_2$, and $O_2$ delivering a GWP improvement 99% lower than $SF_6$. Furthermore, $g^3$ represents the best technical analog to SF6 with comparable economic benefits. We enjoy having 16 leading utilities who have decided to install equipment with $g^3$ and are in service today.

Upon review of the August 15th discussion draft and staff presentation, please consider the following comments on behalf of GE Grid Solutions:

1. <u>Reporting exception for GIE with GWP ≤ 1</u>

The latest revision of the discussion draft contains a reporting exception for GIE with GWP $\leq$ 1, while requiring mandatory reporting for all other solutions.

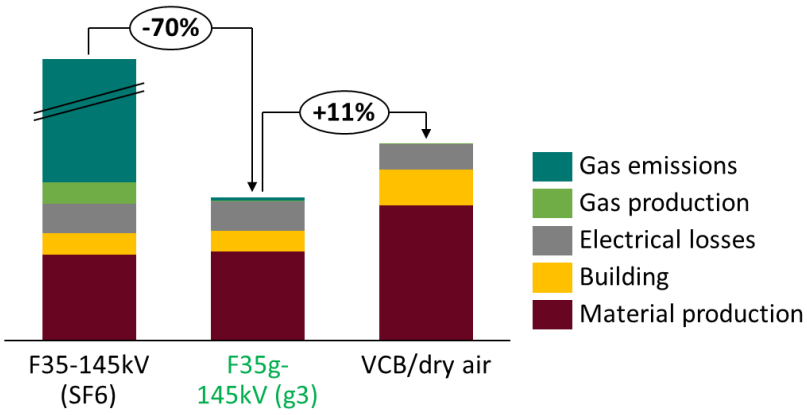
GE does not agree with this limit as this requirement presents in our opinion an unfair obstacle to commercial penetration of some viable SF6-free sustainable solutions like $g^3$ and other Fluoronitrile mixtures. Raising the exemption threshold to $\leq$500 will encourage open competition without favoring any single technology. A typical Utility may indeed consider the lifecycle cost of annual reporting as an impediment to considering a technologically equivalent or superior product. A more commercially and environmentally economical solution may be overlooked to bypass the annual reporting requirement, thus burdening the Utility and manufacturer with a cost that could be disproportionate to any realized CO2e emissions.

To illustrate we have simulated an example: a Utility with an installed base of 2,000 SF6-free gas circuit breakers may be estimated to incur an annual reporting cost of $100 per unit for a total of $200,000 per year, whether the GWP is 22,800 or 500. The Utility receives no reporting relief despite replacing SF6 circuit breakers with nearly two million metric tons of CO2e with alternative gas circuit breakers with just over 10,000 metric tons of CO2e. Furthermore, annual CO2e emissions for SF6-free gas circuit breakers could be as little as 50 metric tons CO2e as compared to nearly 10,000 metric tons CO2e for SF6 equivalents. In this scenario the Utility's emission limit is nearly 12,000 metric tons CO2e for SF6 equipment and less than 61 for equivalent $g^3$ GIE.

To conclude, we believe that having the threshold at ≤500 GWP will level the playing field for all solutions bringing 99%+ reductions vs SF6; increase competition, limit the exceptions presented to Carb and ultimately make it easier for the Utilities to select technology and vendors and thus help dramatically decrease their SF6 GIE installed base.

2. <u>Life cycle assessment methodology:</u>

We believe the CO2e format cannot just be limited to the gas. Indeed, assessing the environmental impact of a solution requires performing a complete life cycle assessment considering all parameters impacting the CO2 footprint. This assessment is required by some utilities and EU Green Procurement Guideline for example. You can see below a Life Cycle Assessment comparison published in 2017 Cigre colloquium PS3 with a CO2 footprint comparison of a 145kV GIS over 40 years of life:




The above comparison demonstrates that for this specific GIE the CO2 benefit of VacuumCB/dry air on the gas CO2e are not enough to compensate the impact of material production.

3. Economic analysis:

We have concerns regarding the economic analysis as detailed in pages 19-21 of the August 15th presentation. Some Utilities might construe the presentation as an endorsement of vacuum technologies and we respectfully advise the CARB Staff to consider the following.

We believe the quoted cost benefit of $600 to $1,000 per breaker per year is not a realistic reflection of modern, reliable gas insulated technology. Also a cost premium ranging from $24,000 to $32,000 per unit to purchase new 72.5kV vacuum circuit breakers has been documented in 2019 through publicly available bid tabulations. It is important to note that this premium does not include the cost for a vacuum monitoring device.

The physical size of any SF6-free circuit breakers should be considered as well. Larger equipment means more energy to produce the materials, transport and dispose at end of life. Land usage should be considered as well as requirements for additional foundation materials. This is linked to our previous point on life cycle assessment.

"Clean Air" circuit breakers still require a gas under pressure, typically a mixture of N2 and O2. Although not required for arc-quenching, the gas serves a critical electrical insulation function and thus any leaks do require maintenance. From our understanding, such circuit breakers use the same sealing systems as SF6 and alternative gas circuit breakers and are therefore subject to the same maintenance. We believe the only relevant cost savings reasonably assumed would be the need for gas handling cart . Just like SF6 (or any other gas) circuit breakers, N2/O2 mixture is critical for the dielectric performance of the circuit breaker, so leaks must be monitored and repaired.

Although vacuum interrupters have been used reliable at low and medium voltage, there is very little real-world service experience at high voltage and in a gas ("clean air") horizontal configuration. In addition, the vacuum circuit-breaker failure rate in high voltage networks is reported to be 39% higher than gas circuit breaker in the CIGRE WG A3.27 survey (The impact of the application of vacuum switchgear at transmission voltages, CIGRE WG A3.27, Cigre Tutorial May2,2013 IEEE).

Also, with the vacuum interrupting medium, there might be no reliable or cost-effective methods to monitor vacuum bottles. If there is a loss of vacuum, this would result in a breaker failure without advance warning if not reliably monitored.

For all these reasons we believe that mechanism reliability and maintenance would be similar between SF6, gas mixtures and vacuum solutions.

Lastly, vacuum users should consider potential additional cost of safety compliance to limit X-ray radiation exposure, especially as for higher voltages application. See for example the CIGRE Technical Brochure No. 589 illustrating that point: "The Impact of the Application of Vacuum Switchgear at Transmission Voltages" Page 62-63, X-Ray Radiation exposure.

4. Detailed phase-out schedule:

We encourage consideration of a more granular phase out schedule to limit the number of technical exception requests. California Utilities have diverse application requirements and the enclosed recommendation will cover common ratings while at the same time proving flexibility to Utilities.

- For 245kV and below, 50/63kA ratings are typically consolidated with one product while 31.5kA/40kA another.
- Continuous current ratings need to be considered, particularly when one considers +50C temperature requirements in much of California rather than +40C defined in industry standards
- X/R is the ratio of the system reactance to the system resistance, which affects the level of short circuit is required to interrupt. Industry standards define circuit breaker ratings based on system X/R of 17. Higher X/R ratio requires the circuit breaker to interrupt higher asymmetrical fault current and is increasingly common in power systems today.

| Voltage (kV) | Continuous Current (Amps) | Interrupting Time (cycles) | Short Circuit Current (kA) | X/R | Recommended Phase-out Date |
|---|---|---|---|---|---|
| **≤ 145** | 3000 | 3 | ≤ 40 | 17 | January 1, 2025 |
| **≤ 145** | 3000 | 3 | 40 <kA ≤ 63 | 17 | January 1, 2027 |
| **145 < kV ≤ 245** | 3000 | 3 | ≤ 40 | 17 | January 1, 2029 |
| **145 < kV ≤ 245** | 3000 | 3 | 40 <kA ≤ 63 | 17 | January 1, 2031 |
| **> 245** | 4000 | 2 | ≤ 40 | 17 | January 1, 2033 |
| **> 245** | 4000 | 2 | 40 <kA ≤ 63 | 17 | January 1, 2035 |

5. Clearinghouse

With respect to the use of an online clearinghouse for manufacturers to self-report as SF6-free technology becomes available, we are supportive of the concept but with the following concerns:

- As the clearinghouse may be used as basis for denial/approval of Exemption Requests, it is critically important for the information posted to be an accurate representation of available "real" products meeting industry standards. As such there must be an independent method of validation ensuring accurate representation of available technology and ratings.
- Manufacturers have invested tens of millions of dollars in development of SF6-free technologies. Reporting on the technologies, even the most basic ratings and available dates may be considered proprietary information and thus the ability to create an accurate view of the market may be limited.
- The clearinghouse should be behind a secure password protected portal with user access strictly controlled, thus ensuring control of proprietary data.

Thank you once more for your consideration. Our GE team is at your disposal should there be additional questions or information required.

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