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SF_6 Reporting Challenges

The U.S. Environmental Protection Agency (EPA) requires that owners and operators of electric power transmission and distribution equipment report emissions of sulfur hexafluoride (SF_6) and/or perfluorocarbons (PFC) for systems that have a total nameplate capacity exceeding 17,820 lbs. (7,838 kg) of those gases. Regulatory agencies in California and Massachusetts require reporting as well. The formula for calculating and reporting emissions to the EPA and state agencies is as follows:

> User Emissions = (Decrease in SF_6 Inventory) + (Acquisitions of SF_6) – (Disbursements of SF_6) – (Net Increase in Total Nameplate Capacity of Equipment Operated)[1]

Where 'Net Increase in Total Nameplate Capacity of Equipment Operated' = the nameplate capacity of equipment installed during the year – the nameplate capacity of equipment retired during the year.

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[1] For a more detailed summary of the GHG Reporting Requirements, see Annex 1 to this document, entitled "Subpart DD: U.S. EPA Greenhouse Gas Reporting Rule"

In order for the actual quantity of user emissions to equal the other side of the above formula, not only must the reporter be able to accurately calculate each of the variables, but the amount of SF_6 contained in each piece of equipment installed or retired must be identical to the stated nameplate capacity in cases of installed or retired GIE, or where the gas is transferred between a GIE and a storage cylinder. The Electric Transmission & Distribution SF_6 Coalition (the Coalition) has published this paper to identify common scenarios in which the weight of SF_6 contained in gas-insulated equipment (GIE) may be different than the figure on the nameplate; explain why nameplate accuracy, until recently, has not been an emphasis for the manufacturer (OEM) or user communities; and explain what GIE users, OEMs, and regulatory agencies can do to promote accurate reporting.

Definitions

- (Gas) Volume: the amount of gas that can be contained in a space enclosed by gas-insulated equipment, measured by length, width, and height and expressed in terms of cubic feet (ft^3)
- Mass of SF_6: weight in terms of pounds (lbs.)
- (Gas) Density: the ratio of mass to volume expressed in terms of pounds per cubic feet ($lbs./ft^3$) and achieved by filling a space with a given pounds per square inch (psi) gauge at a given temperature

Nameplate background

Contrary to what some stakeholders believe, the nameplate figure on a GIE is not intended to indicate the maximum amount of SF_6 that a particular piece of equipment can hold. Rather, the nameplate is meant to indicate the approximate mass of SF_6 that the GIE will hold once it is filled to the proper density.

To facilitate proper filling, OEMs have historically provided a temperature-pressure curve—a chart that provides the end user with the gas pressure that is necessary, at a given temperature, for the GIE to be properly and safely insulated against unintentional electric arcing. It has then been left to the utility to use the chart to fill (or complete filling, in cases where the GIE arrives partially filled) the GIE. The actual mass of SF_6 in a GIE is ancillary for insulation purposes; density is much more important, which is why OEMs have provided and continue to provide precise instructions for filling to the proper density. But because GIE users typically acquire and dispose of SF_6 in units of pounds, the nameplate figure is provided in units of pounds for inventory and recordkeeping purposes.

Much like GIE and its subcomponents, the information on a nameplate is the result of an industry standard. Standards for high- and medium-voltage equipment are coordinated through the Institute of Electrical and Electronics Engineers (IEEE) with input from the OEM and user communities. The current equipment standards do not have an accuracy requirement for the nameplate insulation values. However, Some OEMs now provide accurate nameplate capacities with new equipment, as further discussed below.

Reasons for discrepancy

There are generally two reasons why the amount of SF_6 in GIE might differ from the amount listed on the nameplate: changes in equipment design and field errors.

Changes in Equipment Design

Minor changes in equipment design (i.e. tank and bushing wall thickness) have changed the exact volume of gas that particular models of GIE can hold. Because a change in volume necessarily affects the mass at a constant density, in many cases these changes have resulted in a disparity between the nameplate figure and the pounds of SF_6 actually contained in GIE when filled to the proper density. For example, suppose a particular piece of GIE is manufactured to a gas volume of 200 ft^3 with a required density for insulation of 0.38 lbs./ft^3. When filled to the proper density, this GIE would contain a mass of 526.3 lbs. of SF_6. Now, suppose slight design changes to the GIE model result in a decrease in gas volume to 195 ft^3. Since the equipment still requires the same density to be properly insulated (0.38 lbs./ft^3), the mass of SF_6 in the GIE when filled to that density is 513 lbs., a 2.5% difference.

SF_6 technicians in the field (who typically follow the temperature-pressure guidance in filling GIE) usually assume that when the proper density is attained they will have also attained the stated nameplate capacity in terms of weight. While this assumption does not create any safety issues—as explained above—it does create a reporting issue, since GIE users are required to use the nameplate figure in calculating emission.

Field Errors

As the name implies, a field error occurs when the GIE is in the possession of the end user (e.g., in the "field") and can occur anytime gas is put in or removed from the GIE during commissioning, maintenance, and de-commissioning.

GIE Commissioning and Maintenance

While some OEMs now ship GIE fully charged with SF_6, it has been a common historical practice to ship some types of GIE with minimal or no SF_6, requiring the end user to fill it. As mentioned previously, each GIE is accompanied by a users' manual that contains a temperature-pressure curve, indicating how much SF_6 pressure the GIE requires at each point along a range of temperatures to achieve proper density. Because the gas temperature is difficult to gauge, field technicians often rely on ambient temperature, which can differ up to 40 degrees Fahrenheit from the gas temperature[2]. This disparity leads to a miscalculation of gas density and, consequently, mass. Of course, even if the gas temperature is measured accurately, it is possible for the gas pressure to be improperly measured if, for example, the pressure gauge is not calibrated correctly.

Anecdotal evidence also indicates that SF_6 field technicians will regularly overfill the GIE by a few pounds of gas just to ensure there is a sufficient amount. While this is a perfectly acceptable practice for purposes of safety, it is apparent how this would lead to a different amount of gas in the GIE than the amount that appears on the nameplate.

[2] The SF_6 Coalition recommends use of a precision temperature gauge (accuracy +/- 1.0°F)

GIE Decommissioning

When GIE is removed from service, the SF_6 is removed and stored in a cylinder. While the objective is to completely remove the gas, due to a variety of factors, some of the gas (i.e. potentially up to 10%) may remain trapped in the recovery system and/or the hose that connects the recovery system to the cylinder. Not realizing this, the technician may simply report the "missing" SF_6 as an emission. But in reality, the gas could remain in the hose until it is used again, at which point the SF_6 would be (unknowingly) siphoned into another cylinder or pushed into a different GIE, depending on what the hose is used for. Accordingly, the technician would have reported a phantom emission (explained below).

Negative impact of nameplate discrepancy

In cases where the weight of the SF_6 in the GIE is less than the stated nameplate capacity, owners and operators of GIE are forced to record "phantom" emissions (i.e., emissions that did not occur) if the GIE at issue is involved in a reportable event . For example, installation or retirement of GIE is considered a reportable event since the emissions calculation formula requires an input for the gas in any GIE installed or retired over the calendar year.

The formula also requires an input for the decrease in SF_6 inventory and/or any SF_6 disbursements. Consequently, SF_6 that is syphoned from a storage cylinder into GIE or, conversely, from GIE into a cylinder and stored on-site, would be a reportable event since either scenario impacts the 'SF_6 Inventory' variable of the formula. The same holds true if the gas is syphoned into a cylinder and sent offsite; it would be reported as part of the SF_6 disbursement variable. In any of these scenarios, if the weight of gas in the GIE is less than the nameplate, the reporting entity is forced to calculate an emission for that event.

The following example helps to clarify the scenario:

Status January 1	Status December 31
GIE: Nameplate 100 lbs	GIE: Nameplate 100 lbs (Actual: 105 lbs)
Cylinder A: Empty	Cylinder A: 100 lbs
Cylinder B: 105 lbs	Cylinder B: Empty

Emissions Calculation Formula: (5) + (0) – (0) – (0) = 5 lbs

In the above example, at some point during the year the gas in the GIE is emptied into Cylinder A and, shortly thereafter, the gas in Cylinder B is syphoned into the GIE. This results in a reportable event since the first variable in the formula calls for a calculation of the decrease in the SF_6 inventory (the combined total between both cylinders). In this case, the inventory decreased from 105 lbs to 100 lbs. Assuming other variables remain the same, it appears there has been an emission, even though all of the gas from Cylinder B is safely inside the GIE on December 31.

While the EPA does not currently have an emissions reduction requirement, its corollaries in California and Massachusetts do, and utilities located in those states could be subject to fines and other civil penalties if reported SF_6 emissions for a given year exceed the allowable amount. This amount is expressed as a percentage of Total Nameplate Capacity of Equipment Operated The allowable emissions for California and Massachusetts are as follows:

California		Massachusetts	
2016	5%	2016	3.0%
2017	4%	2017	2.5%
2018	3%	2018	2.0%
2019	2%	2019	1.5%
2020	1%	2020	1.0%

Prevalence of discrepancy

While current data is somewhat limited, empirical information suggests that a large percentage of GIE currently in service and containing the target density of SF_6 contains a different mass of SF_6 compared to what is indicated on the nameplate. Data collected by DILO Inc. showed that out of 221 high-voltage circuit breakers—ranging from 34.5 kV to 500 kV—tested over a period of 36 months, only six (6) contained actual SF_6 mass that was within 1% of the figure on the nameplate.[4]

How to determine SF_6 weight in GIE

There are two (2) possible processes to determine the exact amount of SF_6 in any vessel: pressure/mass calculation and complete SF_6 recovery.[5] The former process entails removing a small amount of SF_6 that is then weighed while monitoring the initial and final pressure. This process takes about 30-60 minutes per GIE, depending on the size. The latter process entails removal of all the SF_6 and then precise weighing of the gas during the process; this takes significantly longer but has a lower margin of error.

Because both processes require de-energizing the GIE, the Coalition recommends that they be performed only during commissioning, maintenance, or decommissioning.

What are OEMs doing to help?

GIE manufacturers are certainly willing to expend effort to help the utility community increase reporting accuracy. Specifically for older equipment, OEMs are prepared to work with their utility customers to formulate a streamlined process wherein nameplates can be amended or replaced with a more accurate figure. The details of such a process are yet to be determined, but it would likely entail the utility customer undergoing one of the processes described above (and discussed in detail in Annex 2) to calculate SF_6 weight and providing corresponding documentation to the manufacturer. For new equipment, OEMs have begun to communicate an "as-filled" value on the GIE, which indicates the precise weight of SF_6 when it leaves the OEM facility.

For logistical and safety reasons, not all GIE is shipped while fully charged with SF_6. Providing the "as-filled" information would provide a verifiable baseline to the utility from which it could make the reporting calculations once the GIE is in service. Finally, as of July 2016, OEMs have proposed including a nameplate accuracy standard to several IEEE subcommittees.

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[3] In cases where the weight of SF_6 exceeds the stated nameplate capacity, this could lead to the reporting of a negative or "hidden" emission.

[4] DILO, Inc. is an SF_6 management and maintenance firm that services hundreds of utilities across North America

[5] For a complete description of pressure/mass calculation and complete SF_6 recovery, please see Annex 2, "Recommended Processes to Support Accurate Reporting of SF_6 Emissions"

How can regulatory agencies help?

The Coalition does not believe that any new requirements or mandates are necessary to encourage more accurate reporting. However, we do believe that reporters will be more likely to accurately measure SF_6 weight if they are allowed to use that figure instead of the nameplate figure for reporting purposes should they so choose.

Absent such a formal allowance, the coalition hopes that state and federal regulatory agencies will at least be open to considering evidence—derived from an agreed-upon process with the corroboration of the OEM—that the reported figure does not reflect actual emissions.

About the Coalition

The Electric Transmission and Distribution SF_6 Coalition, hosted by the National Electrical Manufacturers Association (NEMA), is an industry organization for discussion of SF_6 related issues focused on electric transmission and distribution equipment as well as a forum for industry interaction with public officials surrounding SF_6 reporting and emissions reduction regulations. Current Coalition membership includes representatives of electrical T&D equipment manufacturers, SF_6 producers and distributors, regulatory agencies and industry-related service companies.