Reducing SF_6 Emissions and Consumption

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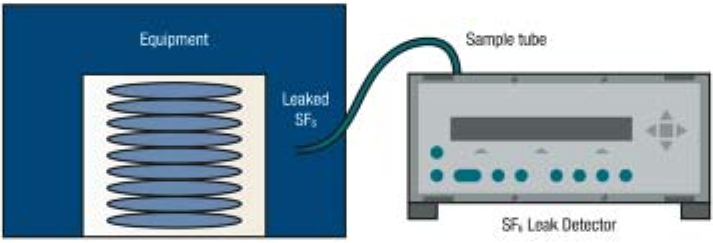
The installed base of electric utility equipment using Sulfur Hexafluoride (SF_6) continues to increase. While the gas started mainly as an insulator for electrical switchgear and control-gear rated for voltages greater than 1 kV, it is now used in cables, tubular transmission lines, electrostatic generators, transformers and complete gas-insulated substations (GIS).

Figure #1

Test Setup For Leak Rate Testing of SF_6 Filled Equipment



The unique technical qualities of SF_6, specifically its high dielectric strength (about three times that of nitrogen) and its excellent arc-quenching properties are driving the increased use. However, the well-documented greenhouse gas concerns of SF_6 and the different maintenance requirements of SF_6 gas-filled equipment represent a challenge for our industry. In addition, regulatory requirements dictating how the gas can be used are expected to become stricter. It is incumbent upon the electric utility industry to develop the most responsible practices and methods for using SF_6. If done right, the industry and its customers can best benefit from the SF_6 molecule's unique properties while minimizing its environmental impact.

Background

Although the chemical and physical properties of SF_6 make it attractive for use in electric equipment, unfortunately, it is a potent "greenhouse" gas with a global warming potential nearly 24,000 times greater than that of carbon dioxide. However, the few alternatives that can be used in its place have their own problems. It is expected that new regulations will allow the continued use of SF_6, but that a strict monitoring regime must be enforced.

In addition to its greenhouse effects, the processes of arcing, sparking, discharging, etc., cause SF_6 to produce by-products. These by-products degrade the insulating qualities of the gas, which result in the gas either having to be replaced or refined. The most dominant by-product, thionyl fluoride (SOF_2), decomposes to SO_2 and HF in the presence of water. In addition to degrading the performance of the equipment, these by-products can be particularly damaging to the health and safety of the workforce.

Cost Concerns

These environmental and safety issues also raise cost concerns. When SF_6 was first used in electrical equipment, it was a relatively inexpensive gas. Letting it leak from circuit breakers was not very costly, and environmental concerns were not prominent. However, times have changed and there are three basic areas where utilities and manufacturers must work together to advance SF_6 gas use:

1. Quality: Better sealed and tested equipment;
2. Monitoring: When leaks happen (they will), find them sooner; and,
3. Handling: Improve SF_6 handing procedures during service and maintenance.

It will require an ongoing industry effort to improve SF_6 handling as environmental pressures increase.

Quality: Start with Better Equipment

The best way to reduce SF_6 emissions is to not use it in the first place. But with no known good alternative, the next simplest way to reduce emissions is to reduce the daily leakage of SF_6 from equipment. Better-sealed equipment has a critical dual advantage of both keeping more SF_6 gas inside the equipment and keeping moisture and other contamination out. Utilities need to work with equipment manufactures to provide certification of leak-tested equipment to the highest standards. This can save considerable cost and problems in the long run while simultaneously helping utilities reduce overall SF_6 emissions.

To meet the final test standards, equipment manufacturers need to use SF_6 leak-testing equipment that is both precise and efficient. The system must be accurate, stable and reliable, and be able to mea-

Figure 2

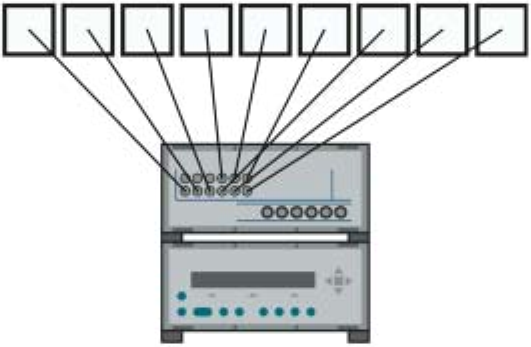
Comparison of different leak rate and the resulting SF6 gas lost to leakage from an installed base of 200 circuit breakers with an average SF6 capacity of 40kg.

Standard / Specification	Leak Rate	Resulting Gas lost through expected leakage
UFGS-33 77 19.00 40	10-7 cc/sec*	0.004 kg
NEMA Guidelines	0.1%	8 kg
IEC 62271-1-2004 Standard	0.5%	40 kg

* As specified by the US Government's Unified Facilities Guide Specification for helium leak test for 5k through 38 kV, 600A load-break SF6 gas switches.

Figure #3

Wide Area Monitoring Using A Single SF6 Leak Detector With An Integrated Multiplexer



sure the total concentration of the gas in a monitored enclosure where the SF_6 equipment is tested as shown in Figure 1 (pg. 51). Although only the total amount leaked is required by the standards, it is advantageous to be able to pinpoint the leaks. This makes it easier to improve the gas-tightness of the equipment before shipping it to the electric utility.

Typical SF_6 leak detectors are sensitive down to ppm (parts per million) levels, but better test equipment is commercially available detecting SF_6 gas down to ppb (parts per billion) levels. This allows for a more accurate leak-rate measurement and allows the equipment manufacturer to perform the required testing more quickly (less time to wait for the leakage concentrations to increase to measurable levels).

To see the impact of different leak rate performance, Figure 2 (pg. 51) compares the annual losses for equipment built to IEC standards, NEMA standards and a U.S. government specification. The NEMA guideline for newly manufactured circuit breaker SF_6 leak rates is 0.1 percent/year. This is significantly tighter than IEC's standard (62271-1-2004) for new equipment of 0.5 percent/year, but still looser than that required by some electric utilities specifications.

Monitoring Installed Equipment

To safeguard the environment against leaks from installed equipment, future regulations may require that monitoring systems be installed at transformer and switchgear stations. Such a system must have low detection limits and maintain its stability over long periods of time. A multipoint sampling system would offer fuller coverage, and a system that can operate unattended for long periods of time would release valuable manpower resources to deal with other tasks. Figure 3 (above) shows how a single gas detector can be used to monitor a wide area using a multiplexer. Samples can be drawn from up to 12 different points via tubes, which are connected to the multiplexer's inlet. The outlet from the multiplexer is fed to the monitor, which is calibrated to a detection limit low enough (e.g. 5 ppb) to meet the customers' specification.

It was found that a LumaSense SF_6 Leak Detector coupled to a multiplexer could meet the demands both for monitoring in the field and for finished equipment approval tests. The monitor uses a unique photoacoustic spectroscopy (PAS) measurement technique that takes advantage of SF_6's ability to absorb infrared light. This technique enables extremely accurate SF_6 gas detection down to 5 ppb, while still being capable of measuring accurately over a wide dynamic range. This enables manufacturers to not only monitor SF_6 presence, but to measure it quantitatively. The monitor can be moved around without any loss in accuracy and without needing to be recalibrated. This enables test engineers to locate areas that are a cause for concern.

Going Forward with SF6

Utilities and equipment manufactures must work together to reduce SF_6 emissions and improve equipment service life by testing and improving the quality of SF_6 seals. Commercially available equipment can enhance our use of SF_6. By using leak detectors with lower detection limits and great precision, manufacturers found that the time required for their approval tests could be reduced considerably, thereby boosting productivity by as much as a factor of four.

To monitor a switchgear "farm," the monitors can be connected to a multiplexer. The systems are able to monitor unattended for extended time periods. The monitor's extended self-test routines maintain the reliability of the results, which are available online or can be dumped from memory when required.

Utilities have discovered that by installing high-grade SF_6 leak detectors not only monitored for leaks, it was also able to detect low levels of gas, thus safeguarding both the environment and the health and safety of the workers while the equipment is operating.

Finally, utilities that have focused on improving their equipment and their SF_6 gas handling processes have found a net cost savings. There are costs associated with monitoring and training, but the savings realized from reduced equipment maintenance and less purchasing and re-filling of SF_6 gas were about three times greater. ‹‹

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