EPRI

technical update

EPRI SF_6 (Sulfur Hexafluoride) Research—Past Highlights and Future Plans

Substation Operation and Maintenance

Introduction

EPRI has performed extensive past research on SF_6. A review of this body of work sets a strong foundation for discussions on the present and future research in EPRI. Starting as far back as 1978, EPRI began work on a dielectric fill gauge that would perform the dual function of providing an early warning of gas leaks plus continuously monitor for moisture in the SF_6 [1]. In the 1980's, research was conducted on arc by-products in Gas-Insulated Equipment [2]. This foundational work set out to develop a database for SF_6 decomposition products generated by electrical discharges within gas insulated equipment. As early as 1981, EPRI held the Workshop on Users Experience with Gas-Insulated Substations [3] where the topics of SF_6 handling safety and SF_6 gas analysis were presented and debated. 1982 saw EPRI publish two and a half years of theoretical and experimental research looking for a possible replacement for SF_6 [4]. No single gas was found to be superior to SF_6—but a few promising gas mixtures were identified for further examination.

From 1985, the focus of the SF_6 research shifted towards gas insulated substations—but continued the research into the handling of arcing by-products and the use of SF_6 [5,6]. The work was summarized in a two-volume report on GIS reliability. The research was complimented by the 1985 International Symposium on Gas Insulated Substations—sponsored by Ontario Hydro, Canadian Electrical Association, and EPRI.

In the 1990's, the research focused on three areas:

1. Aging of Spacer Insulators in SF_6 Insulated Bus.
2. Fault location techniques for GIS using IR (infra-red).
3. Research on SF_6 Handling and Recycling that lead to the publishing of the first version of the EPRI Practical Guide to SF_6 Handling Practices [7]. This document is updated every two years to remain abreast with the latest technology and practices.

Research Objectives

The drivers for the present-day EPRI SF_6 research program can be summarized under the following broad headings:

- *Reduce operating costs*. For a utility, this is achieved through lower SF_6 loss and fewer call-outs. Manpower for unnecessary SF_6 top-ups is a large, avoidable cost that this research aims at reducing.
- *Improve reliability.* For a utility, this is achieved through reducing risk through having fewer live top-ups. Any activity performed on in-service, energized equipment creates an elevated risk of failure. Research is aimed at reducing the attention SF_6 filled equipment needs in service.
- *Extend equipment life.* For a utility, this is achieved through improved gas quality and improved diagnostic capabilities.
- *Protect the environment.* Through reduced SF_6 emissions.
- *Improve safety.* For a utility, this is achieved through two routes. The first is through effective on-site SF_6 analysis, which provides an early warning of hazardous by-products before a compartment is opened for maintenance. The second is through improved, safer SF_6 handling practices. The EPRI *Practical Guide to SF_6 Handling Practices* [8] presents utilities with up-to-date knowledge in this area.

The above research objectives are met through research into three key areas:

- SF_6 Leak Research,
- SF_6 Analysis Research
- SF_6 Handling Research

Each area of research is discussed in detail below.

SF_6 Leak Research

The focus of this research has been the EPRI SF_6 Camera—a collaborative development together with LIS (Laser Imaging Systems), Punta Georgia, Florida. The EPRI SF_6 Camera allows the visualization of SF_6 leak sites using a unique video detection system. There are two primary benefits over traditional SF_6 leak detection (halogen detectors and soapy water)—the ability to perform leak detection without having to take equipment out of service and the dramatic reduction in time necessary to detect a leak site. Improved SF_6 leak detection is important due to the following factors:

- The potential impact of released SF_6 on the environment
- The increased cost of SF_6
- The increased operational risk from regularly filling live equipment [9]

The technology exploits the strong IR (infra-red) absorption of SF_6 gas to make it visible to the camera operator. A laser illuminates the leak area at a wavelength that coincides with strong spectral absorption of SF_6. An IR camera focused on this same area displays a real-time image. Areas of the image where SF_6 is present strongly absorb the reflected IR, which allows SF_6 leaks to be visualized in real-time as a plume of black gas. Because of the strength of the optical absorption by SF_6, the laser camera is sensitive to SF_6 leaks as small as 2lbs/yr, viewed at distances as far as 100ft [10].

Traditional techniques require the operator to be in close proximity to the leak. With the EPRI SF_6 Camera, equipment may be inspected from ground level. This long range makes it possible to rapidly inspect substation equipment while energized [10]. The latest version of the LIS/EPRI SF_6 Camera is seen in Figure 1.

Figure 1. The latest version of the LIS/EPRI SF6 Camera (TG-30).

SF_6 Analysis Research

The analysis of SF_6 by-products is important for the following reasons:

- SF_6 by-products are toxic and corrosive. SF_6 analysis before opening of SF_6 equipment can provide valuable guidance on the personal protection to apply.
- The purity of SF_6 is important for the long-term performance of SF_6 insulated equipment. SF_6 analysis after commissioning or after maintenance is an important step in confirming that the SF_6 meets the purity requirements of the equipment manufacturer.
- SF_6 analysis can serve as a valuable diagnostic tool. Problems within SF_6 insulated equipment such as sparking, arcing or overheating generate specific and known by-products. SF_6 analysis can quantify these by-products through taking a small sample of SF_6 gas while the equipment is in service. Through this non-invasive technique, early warnings can be obtained about internal problems that could lead to eventual failure of the equipment.

EPRI sponsored research in collaboration with Powertech Labs (Vancouver) has resulted in the development of two devices for detection of SF_6 byproducts (See Figure 2):

- The first is a portable SF_6 (DPD) Decomposition Products Detector. The major application of the DPD is to provide a quick and accurate measurement of the sum of the dominant SF_6 decomposition products. This instrument is portable, rugged and easy to operate and is able to handle sampling from energized equipment at system pressure. It is advantageous to test the gas at the source due to the unstable nature of low level decomposition products and to detect faults quickly without having to wait for lab analysis. With this detector, rapid screening of SF_6 by-products is possible to quickly locate problems and minimize outages. Personnel safety can also be rapidly assessed before maintenance begins so that appropriate procedures and precautions can be implemented. The final advantage of the DPD is its high sensitivity, which allows the testing of new gas against the standards for by-product limits [11].
- The second product is a more sophisticated, tailored commercial MicroGC (Gas Chromatograph). The MicroGC is complimentary to the DPD. If, in its quick scan of the equipment, the DPD indicates a problem with the SF_6 by-product level, the MicroGC can be used to fully investigate the levels of each individual contaminant and more accurately predict the cause of the problem and the course of action required. The MicroGC is sensitive enough to provide an answer on whether SF_6 is fit for reuse or fit to stay in service. In conjunction with the DPD, a full assessment of both in-service and new SF_6 can be performed.

SF_6 Handling Research

EPRI has conducted a large volume of SF_6 research, and identified a need to distill many of the practical lessons learned into the *Practical Guide to SF_6 Handling Practices*. The guide was originally developed in 1999 [7] and has been revised every 2 years to keep it relevant to utilities [8].

The guide is not intended as an industry standard, but is for use as a reference in formulating utility-specific policies. The guidelines are used in conjunction with manufacturers' recommendations, and where applicable, with national, state or provincial, and local regulations.

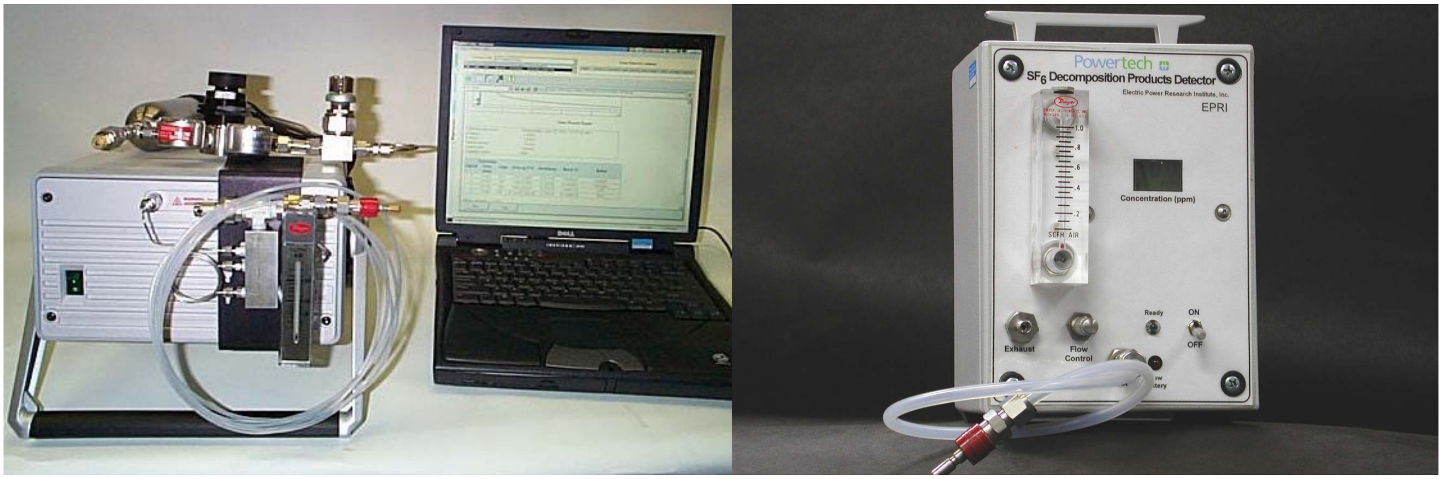

Figure 2. Left: Tailored MicroGC. Right: EPRI/Powertech Decomposition Products Detector.

The handling guide applies to electrical equipment employing SF_6 gas as an insulating and/or interrupting medium. The guide specifically addresses the following issues:

- Classifications for switching and non-switching equipment types along with indoor and outdoor applications
- Risks, warning signs, and written instructions for various low-, intermediate-, and high-risk situations as well as abnormal operating conditions
- Handling procedures for equipment commissioning, maintenance, and failure situations, with information on the use of gas carts for temporary SF_6 storage during maintenance tasks
- Personal protective equipment, with an emphasis on clothing and respiratory devices
- Disposal and environmental protection practices for clean and contaminated SF_6 gas as well as solid decomposition products under normal and abnormal conditions
- Cylinder transportation, handling, and storage, focusing on U.S. Department of Transportation Regulations
- Latest and emerging techniques dealing with utility related SF_6 handling, recycling and analysis issues

The topical organization of this material keeps information at a practical level for easy field access. Supplemental appendices offer further explanatory and background information on SF_6 handling.

Future Research

In the near future, EPRI Research is planning to address the following needs:

- Improved Leak Location. EPRI is constantly tracking the development of improved SF_6 camera leak location techniques. There are some promising developments on the horizon that are under investigation for 2003 and 2004.
- GIS Condition Monitoring. GIS stations are at critical nodes in the grid and a failure has a large impact on a utility's performance. GIS stations are SF_6 insulated so the SF_6 analysis technique developed in past research can be effectively applied to predict failures in GIS. The focus for research will be on this and two other diagnostic techniques:
  - UHF Detection
  - Acoustic Emission
- SF_6 is a powerful Greenhouse Gas with a 100-year GWP (Global Warming Potential) of 23,900—that is, 23,900 times more powerful than Carbon Dioxide. Even though SF_6 presently has a negligible impact on Global Warming, concerns have been raised of the long-term impact of SF_6 on the environment. The electrical energy industry uses 80% of SF_6 produced. Decisions made on the future use of SF_6 could have an enormous impact on our business. The challenge facing utilities is that the science and politics of SF_6 and Global Warming are complex and in continual flux. Predicting the future in this critical area is important but difficult. EPRI is well positioned to assist utilities in this decision-making task through this SF_6 research project. Future EPRI research will work closely with the EPRI Environmental group to leverage their modeling and policy experience. What will be produced is an easy-to-understand Executive Summary that will be continuously updated to keep current with policy changes and technology developments.

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About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

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