Strategy for Eliminating SF6 in Factory Production Processes for High Voltage Circuit Breakers

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Philip C. Bolin (Consultant)

David Giegel (Quality Manager), John Larson (Quality Engineer), Rich York (Advisory Engineer)

Mitsubishi Electric Power Products, Inc.

Warrendale, PA USA

Why Focus on High Voltage Circuit Breakers?

- Large amounts of SF6 involved
- Outdoor high voltage SF6 circuit breakers are in wide use in air insulated substations (AIS) to temperatures of down to minus 50 degrees C
- Available alternatives to SF6 circuit breakers are either very expensive (such as CO2 breakers) or need to be enclosed (practical only for gas insulated substations (GIS))

Use of SF6 in Factory Production Processes

- Component leak check (normally by vendor-not considered here)
- Factory leak check cast aluminum tanks before use-evacuate air and fill with "shop" SF6, check for leaks, reclaim "shop" SF6 and backfill with air
- Assemble Component parts onto tank, evacuate air and fill with "shop" SF6
- Resistance measurement of main current path
- High voltage withstand test
- Mechanical operation test
- Fully assembled leak check –will emit SF6 if leaks are present
- Reclaim into "shop" SF6 storage equipment
- Fill evacuated circuit breaker with the amount of "new" SF6 to be shipped inside the circuit breaker to user (largest units require site assembly and are shipped sealed with dry air – then evacuated and filled with new or reclaimed SF6 at the site)

Elimination of SF6 Emissions

- Standard leak rate limit has improved over the last two decades from 1% per year to 0.5% per year and will soon be 0.1% per year
- Factory production emissions are generally stated to be about 1%
- Elimination of SF6 from leak checking of large cast aluminum circuit breaker tanks before use completely eliminates SF6 emissions from this part of the factory production process

Emissions of SF6 in Factory Production

- Handling emissions due to seals of tank openings connections (hoses/valves) to shop gas system – negligible except for accidents/errors
- Transfer emissions due to residual level of SF6 left in tank and later released to atmosphere
- Contamination (errors, accidents or from the partial evacuation of air before filling with SF6) eventually results in need to replace "shop" SF6
- Large leaks due to defects in parts or assembly or accidents (such as premature rupture disk bursting , broken bushing, etc.)

SF6 Large Tank Leak Check to 2012

- Cast and fully machined tank was washed and dried.
- Tank was fitted with flanged plates and ports
- Evacuated to a low pressure (1 torr), held for 30 minutes to eliminate moisture
- Filled with “shop” SF6 to 90 psig
- Leak tested using a sensor sensitive to lower than 1 ppm SF6 after wrapping with plastic films and bags. A 90 minute hold ensured adequate sensitivity
- If no leaks were detected the SF6 was evacuated back into the “shop” gas system to a low residual pressure .
- Zero ODP (Ozone Depleting Potential)
- 23,500 GWP (Global Warming Potential)

Helium as a Leak Check Gas

Well established industrial technique

- Very sensitive (however atmospheric background is 5 ppm)
- Inert gas -- safe, will not react with materials of item being leak checked
- Expensive facility when using a vacuum chamber– especially for large tanks
- Requires highly trained personnel – but can be automated
- Utilizes scarce resource – however new supplies continue to be discovered (Crude price about $100/Mcf in 2016)
- Zero ODP and GWP (escapes from atmosphere due to light weight of molecule)

Hydrogen as a Leak Check Gas

- Well established industrial technique using premixed gas (5% H2 and 95% N2)
- Safe for personnel (5% mix not burn when released to atmosphere)
- Sensitivity of typical sensors about 15 ppm
- Atmospheric background < 1 ppm due to high reactivity and mobility
- Zero ODP and GWP

Selection of Hydrogen

- Lower cost than helium
- Simple facility modifications- only equipment addition is a hydrogen tuned sensor
- Sensitivity better than affordable helium system for large tanks
- No need to reclaim, so cycle time less

Considerations for using Non-SF6 Alternative gasses for production testing of SF6 breakers

Advantages:

- Ozone Depletion Potential (ODP) Zero
- Global Warming Potential (GWP) reduced from 23,500 to 2100 or lower
- Effective as leak check gas for fully assembled circuit breaker

Investigation necessary:

- Determine proper mix and pressure to provide:
  - Similar dielectric strength to SF6 for high voltage withstand testing
  - Match SF6 during mechanical operation in terms of overall effects of the mixture -- viscosity, flow, pressure in puffer interrupter (contact travel curve)
- Confirm compatibility with all materials used in breaker
- Confirm pressure will not jeopardize pressure relief devices (rupture disks)
- Safety concerns
  - Decomposition byproducts are a concern if testing involves arcs or partial discharge
  - Evaluate toxicity of mixture chosen and decomposition byproducts
  - Follow guidance of IEEE/IEC investigations and standards impact