SF6 Leak Management, Repairs, and Considerations

November 15, 2017
Michael D. Wolf, PE
Doble Engineering Co.
Why Bother?

- Industry has come a long way with gas handling procedures.
- Compare procedures from 1980s – totally unacceptable practices in modern world (see below).
- Still room for improvement – even with stricter, environmentally conscious practices.

a. Open the filling valves and release the SF₆ gas to atmosphere. Disconnect the line connection from the load side bushing.
Agenda

- Prioritizing leaking equipment
- Locating the leak
- Develop a plan
- Considerations for repairs
- Take-aways
Prioritizing Leaking Equipment

- Plenty of leaking equipment
- Impossible to address every leak right away
- Need to prioritize and focus efforts
- Develop a list of worst performers on system based on emissions, not just quantity of top-off work orders
  - 550kV breaker filled twice yearly vs 15.5kV breaker filled three times
- Add criticality multiplier
  - Major transmission hub, critical customer, CEO lives on feeder
Prioritizing Leaking Equipment

- Collect work orders (WO) annually

- Does added weight go into WO?
  - Sum up weights for all leaking equipment
  - Easiest, cleanest method
  - Requires scales at bottle locations or mass-flow meters

- Pressure before, pressure after, and temp?
  - Make some assumptions, sum up

- Just that gas was added?
  - Assume fill from alarm to rated, sum up
Prioritizing Leaking Equipment

- Start at the top of the list
- Visibility to management to show progress, reduced emissions
- Refresh list annually for constant improvement
- Be practical with expectations
Agenda

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Locating the Leak

- Different leak detection methods exist
  - SF6 sensitive camera
  - Handheld gas detector (sniffer)
  - Bubble-mix (snoop)

- Varying sensitivities, limitations and drawbacks

- Leak may not be “active” during initial survey
  - Seasonal with temperature
  - Daily with temperature
  - “Non-linear” leak when pressure drops
SF6 Camera

- The BEST method of finding leaks on energized equipment
- Can detect very small leaks (0.5lb SF6 annually)
- Get visual representation of leak location, severity
- Can capture digital image of leak
- Allows multiple attempts to locate leak without taking repeated outages
  - May have to re-visit during winter or summer to catch leak while it is active
  - Colder temp leaks more common
SF6 Camera
SF6 Camera Limitations

- **Cost**
- Difficult to use infrequently – experience pays off
- **Wind conditions**
- Need light from sun
- Background can be challenging – clouds vs. blue sky
- Reflections from other surfaces can be misleading

Video courtesy of FLIR
Handheld Gas Detector (Sniffer)

- Simple, low-cost device
- Extremely sensitive
- Easy to use, infrequent use not a challenge
- “Scale” to determine concentration of gas
- Can slightly open cabinet, bagged flange and insert probe
  - Easily detect leak in control cabinet tubing, switches, gauges
Handheld Gas Detector (Sniffer)
Handheld Gas Detector Limitations

- Can be too sensitive
  - False positives on non-leaking pole
- Wind can be challenging for precise location
- Dusty, contaminated environments challenging
- Can only check grounded components while equipment is in service
Bubble Mix (Snoop)

- Commercially available soapy-water solution
- Can make with diluted liquid dish soap, 20:1 and a spray bottle
- Spray on flanges, tubing, or porous casting
- Will bubble up when gas tries to get through soapy water
- May have to wait for pressure to build to form bubble
Bubble Mix Limitations

- Cannot spray on live parts while in service
- Grounded components only
  - Easier if general location is known by handheld detector or camera
- Less useful when below freezing
- Otherwise a very accurate locating technique
Offline Methods

- Bag check

- Plastic sheeting or garbage bags over flanges to accumulate leaking gas
  - Tape up ends tightly
  - Bag all flanges, inspection ports, bushing top plates:
  - Let sit for 2h+ to build leaking gas
  - Put sniffer into “bag” and check
  - Bubble mix to determine specific location on leaky flange/casting
Offline Method Limitations

- Outage required
- Leak may not be active
- Ambient temperature
- “Nonlinear” leak
- Lots of expense/maintenance costs

Image courtesy of Mitsubishi Electric Power Products, Inc.
## Comparison

<table>
<thead>
<tr>
<th></th>
<th>SF6 Camera</th>
<th>Handheld Gas Detector (Sniffer)</th>
<th>Bubble Mix</th>
<th>Offline Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benefits</strong></td>
<td>Single best leak detection method</td>
<td>Low cost instrument, high sensitivity, little experience required</td>
<td>Pinpoint accuracy</td>
<td>Pinpoint accuracy, little experience required</td>
</tr>
<tr>
<td><strong>Drawbacks</strong></td>
<td>Cost, weather conditions</td>
<td>False positives, weather conditions</td>
<td>Grounded components only, weather conditions</td>
<td>Equipment out of service, weather conditions, cost</td>
</tr>
</tbody>
</table>
Managing Leaking Equipment

- Use camera during cooler months to attempt to identify “challenging” leaks

- Attempt to apply heat to keep contraction down in cold months
  - Electric heating tape

- Collect detailed records if two-pressure system (2-3 times daily)
  - HP and LP system pressures and temps, compressor hours and oil level, heater current

- Online filling tools exist to keep just above alarm – minimize emissions
Managing Leaking Equipment

- Adding gas while equipment is energized vs. deenergized
- Decision to make while managing leaking equipment
- Always refer back to manufacturer’s recommendations
- Inherent risks involved
- Safety considerations should be foremost priority
- Be mindful of tolerances – gauge, density switch… assume +/- 4 psig
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Developing a Plan

- External support required? In house knowledge sufficient?
- Test purity, moisture, byproducts before repairs
- Plan ahead – what kind of pre-filter do you need?
- What kind of PPE do you need?
Developing a Plan

- Enough cylinders under vacuum if scrapping gas?
- Enough cylinders of new gas to completely fill breaker, if scrapping gas?
- Properly sized handling equipment
Parts and Kits

- Parts?
  - New gaskets for each disturbed point
  - New desiccant

- Correct lubricant for flanges/o-rings

- Kits usually available from manufacturer

- Never re-use gaskets

- Ensure correct parts for application
  - Variability even within breaker models
  - Consult manufacturer to verify serial number works for “on-the-shelf” parts already on hand
Special Considerations for GIS

- Significant amounts of gas in zones
- Large holding equipment needed OR many cylinders under vacuum
- Large handling equipment needed to recover gas and evacuate completely
- Older GIS used welded bus – may have to cut… major work involved
- Check with manufacturer for commissioning requirements after repairs
  - Hi-pot, bus conditioning
Plan Target Pressures

- Workforce needs guidance on expectations

- How low of a vacuum to recover gas down to?
  - Recommend <10 Torr
  - Shoot for 3.5 Torr
  - Check with pump blanked off
  - For smaller equipment, <1 Torr

- How low of a vacuum to evacuate space after repairs?
  - Recommend 1 Torr, pull for 1 hour
  - Can’t get low enough? Leak in system

- What limits for a rise test?
  - Less than 2 Torr rise in 2 minutes for hoses
  - Less than 2 Torr rise in 1 hour for breakers
  - Pressure increase, then level off? Moisture boiling
  - Pressure increase, no leveling? Leak in system
Topic Headline

- Someone, somewhere has done this same job
- If unsure about job, call for advice!
  - Doble
  - Dilo
  - Manufacturer’s field service
  - Field service contractors
  - Colleagues
Agenda

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Considerations for Repairs - Safety

- Recognize and identify the hazards

  - High voltage
    - Isolate, ground, and tag

  - Low voltage
    - Disconnect control power, ensure AC feed to handling equipment protected

- Stored energy in mechanism
  - Release spring tension, bleed down air or hydraulic pressure

- High pressure gas in breaker, handling equipment
  - Always use regulators, leak check equipment under vacuum prior to pressurizing
Considerations for Repairs - Safety

- Harmful compounds formed if arc byproducts combine with moisture
- Test gas prior to recovery
- Moisture, purity, arc-byproducts
- If contaminated – avoid unnecessary exposure to handling equipment by utilizing external cylinders for storage
- If contaminated – follow company guidelines on SF6 arc byproduct handling
- Suits, respirators, waste-controls, etc…
Considerations for Repairs – Gas Handling Equipment

- Use shortest hose runs as practical to limit pressure drops
- Avoid small diameter fittings if possible
- Pre-filter selection
  - Different filters available for different needs
- Ensure adequate AC power feed
  - Rotary phase converter, step up transformer required?
  - Supply AC from dedicated breaker in panel
Considerations for Repairs – Gas Handling Equipment

- Check handling equipment one section at a time prior to handling gas
  - Pull vacuum while hoses, fittings, or valve/gauge trees are added
  - Valve off as each section is added, perform vacuum rise test to check for leaks
  - Denatured alcohol spray to check suspect fittings

- Pulling to vacuum (0 psig) isn’t “good enough” while recovering gas
  - For typical SF6 system, ~20% of gas remains at 0psig
  - Recover gas as far down as possible, keeping in mind diminishing returns
  - Record recovery vacuum level for future reference
Considerations for Repairs – Mixed Gas Systems

- SF6/N2 mixes – can’t liquefy nitrogen like SF6, will over pressurize system during recovery
- Onboard storage may not be adequate since gas can’t liquefy like pure SF6
- Use external cylinders under vacuum for storage
Considerations for Repairs

- Perform electrical and gas tests before going into the breaker
- Recognize issues before they become “surprises” later on
- Identify other problems to address while breaker is out
  - Gas quality tests (moisture, purity, byproducts)
  - First trip analysis
  - Travel and timing
  - Main circuit resistance (ductor)
  - Power factor/capacitance
- Different requirements for GIS sections
  - Consult with manufacturer
  - Warranty concerns
Cleanliness

- Keep unnecessary debris out of the tank
  - Overnight protection
  - Clean all exposed tanks after repairs
  - Use tack-cloth to remove particulates
  - Denatured alcohol and low-lint wipes

- Vacuum out tank
  - HEPA vac, long tube extensions, brush nozzle
Cleanliness

- Sealing surface cleanliness
- Corrosion on flanges may be significant
- Close attention will lower risk of “return trip”
- Abrasive pads and denatured alcohol
- Remove all particulates, fibers, hairs before reassembly
Gasket Lubrication

- Lubricate gasket with silicone grease
- Remember compatibility – avoid silicone grease if using silicone gaskets
- Fluorosilicone grease will always be compatible
- Lubricate outside the gasket groove with fluorosilicone grease
- Acts as moisture and contaminant barrier, protecting gasket and groove
- Don’t over-apply
Bolting Back Up...

- Torqueing
  - Use specified torques during reassembly
  - Tighten in a pattern
  - Overtightening can deform gasket, compromise sealing ability
- Be considerate of desiccant
  - Have everything in place prior to opening desiccant to atmosphere
  - Start vacuum as soon as two bolts are snug on last flange
- Be considerate of “open-time”
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Take Aways

- Workforce needs guidance and procedures
- Always follow safe work practices
- Leaks can take time to locate
- Test equipment before AND after repairs
- Always pull SF6 down below 10 Torr when recovering SF6
- Environmental regulations only becoming more strict – set up policies and procedures to adhere
SF6 Leak Management, Repairs and Considerations

Michael D. Wolf, PE – Doble Engineering Co.
Sacramento, CA
617-393-3071
mwolf@doble.com