SF6 Inventory & Tracking Challenges

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Overview

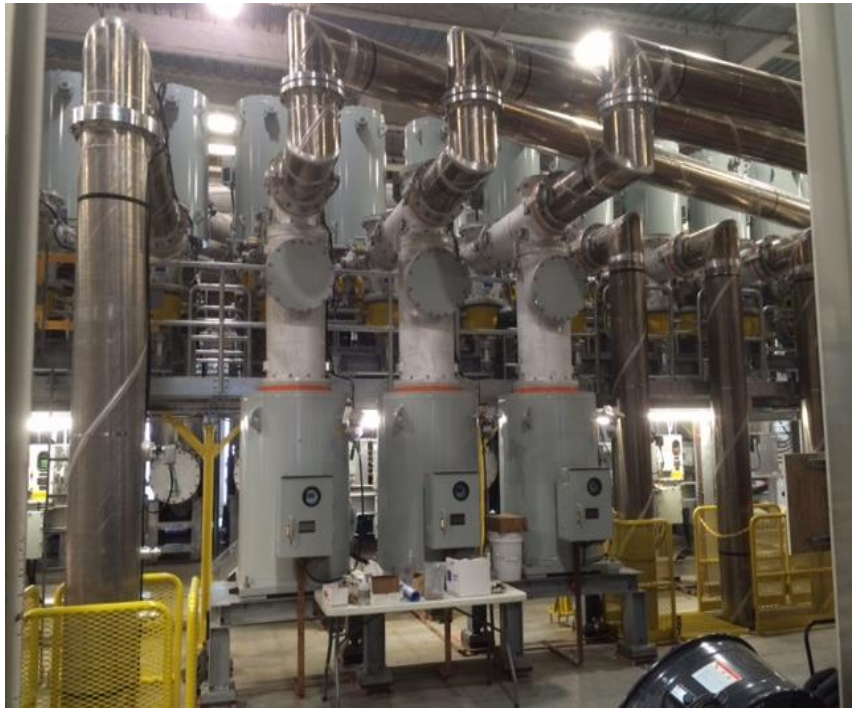
- Southern California Edison currently has 4694pieces of GIE in service (4 GIS Subs) ~ 850,000 lbs.
- SCE started actively tracking SF_6 emissions as part of EPA's voluntary emission reduction program in 1998
- Emission reporting became mandatory in 2011 for both EPA as well as CARB (CA Air Resources Board)
- CARB limits SF_6 emissions to 1% compared to nameplate capacity starting 2020

Major Challenges for SF_6 Users

- Additional reporting requirements
- Operational / Procedural
  - Inexperience / Infrequent SF_6 handling
  - Handling / Measuring equipment
  - Missing info on work orders
- Tracking / SF_6 Management
  - Installed GIE / Nameplate issues
  - Data transfer not in real time
  - Patchwork of different customized programs and Excel spreadsheets to monitor inventories and emissions
  - Disconnect between E&H and field personnel
  - Cylinder tracking / Multiple entry points for cylinders
  - Tracking each SF_6 movement
  - Difference between US EPA and State reporting

Reported Emissions

- Actual / Hard Emissions
  - Leakage from GIE
  - Handling Emissions
- Tracking Emissions
  - Recordkeeping Inaccuracies
- Nameplate Issues
  - Nameplate Discrepancies
  - Nameplate Inaccuracies



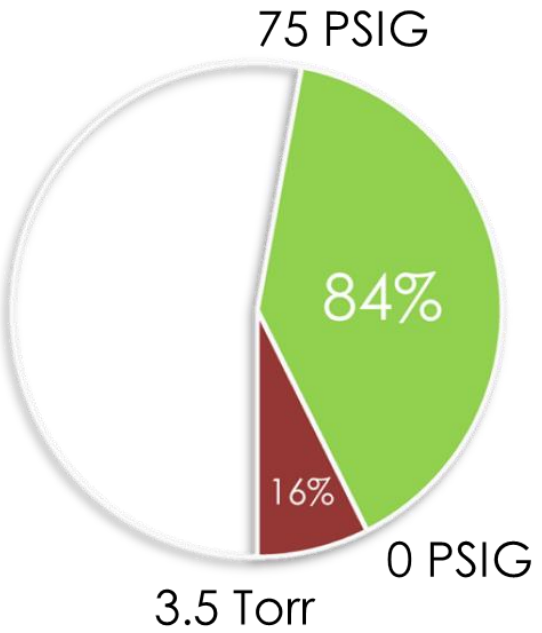
Federal EPA 98.306 – Data Reporting Requirements

- Each annual report must contain the following information for each electric power system:
  - Nameplate capacity of equipment (lbs)containing SF_6
  - Existing at the beginning of the year (excluding hermetically sealed-pressure switchgear)
  - New during the year (all SF_6 insulated equipment, including hermetically sealed-pressure switchgear)
  - Retired during the year (all SF_6 insulated equipment, including hermetically sealed-pressure switchgear)
  - Transmission miles (length of lines carrying voltages above 35 kV)
  - Distribution miles (length of lines carrying voltages at or below 35 kV)
  - Lbs. of SF_6 stored in containers, but not in energized equipment, at the beginning of the year
  - Lbs. of SF_6 stored in containers, but not in energized equipment, at the end of the year
  - Lbs. of SF_6 purchased in bulk from chemical producers or distributors
  - Lbs. of SF_6 purchased from equipment manufacturers or distributors with or inside equipment, including hermetically sealed-pressure switchgear
  - Lbs. of SF_6 returned to facility after off-site recycling
  - Lbs. of SF_6 in bulk and contained in equipment sold to other entities
  - Lbs. of SF_6 returned to suppliers
  - Lbs. of SF_6 sent off-site for recycling
  - Lbs. of SF_6 sent off-site for destruction

Real World SF_6 Emission Tracking Problems

- 4/14/2016 – Substation personnel removes SF_6 from GIE containing 340 lbs per nameplate. Upon completion, 245 lbs. is stored in cylinders.
- 5/10/2016 – Environmental questions discrepancy – Substation personnel blames inaccurate nameplate
- Problems & Possible Errors:
    - Long delay between work being performed and records being updated
    - Density was not checked/recorded prior to gas recovery
    - Recovery blank-off pressure unknown – incomplete recovery
    - Residual SF_6 in recovery system not accounted for
    - Weighing inaccuracies (weight scale and/or cylinder TW)
    - SF_6 emission on the pressure side of equipment (i.e. recovery system/hose leak)
    - Nameplate Inaccuracy
    - All of the above

Eliminating SF_6 Recovery Emissions



$$\left(\frac{P_I - P_F}{P_I}\right) \times 100 = \%recovered$$

P_I = Initial breaker pressure in mmHg(absolute)
P_F = Final breaker pressure in mmHg(absolute)

Impact of Blank-off Pressure on SF_6 Recovery

- GIE containing 340 lbs @ 85 PSIG
- Recovery to 0 PSIG / 760 Torr — 290.0 lbs removed / 60 lbs lost
- Recovery to 200 Torr — 326.0 lbs removed / 14 lbs lost
- Recovery to 50 Torr — 337.0 lbs removed / 3 lbs lost
- Recovery to 5 Torr — 339.7 lbs removed / 0.3 lbs lost

Personnel recovering should be instructed to always reach a blank-off pressure of 5 Torr / for GIE containing < 50 lbs 35 Torr

Properly designed tracking program to immediately alert personnel if recovered gas does not match nameplate

Step by Step SF_6 Recovery – Verifying Nameplate

- Verify Temperature/Pressure for proper density
  - Any deviation in pressure will result in nameplate discrepancy
- Recover to < 5 Torr (< 35 Torr for GIE containing < 50 lbs)
  - Difference in recovered SF6 not measurable in GIE containing < 50 lbs
- Use calibrated mass flow scale or weight scale
  - Mass flow scale preferred as it eliminates cylinder TW inaccuracies
  - If using weight scale verify that residual SF6 has been removed from recovery system
- Document blank-off pressure
- * Above info should be reported/saved by tracking software/program

SF_6 Inventory Management & Tracking Challenges

- Topics of discussion
- "Please come back next month – I'm working on our EPA/CARB SF_6 Reporting"

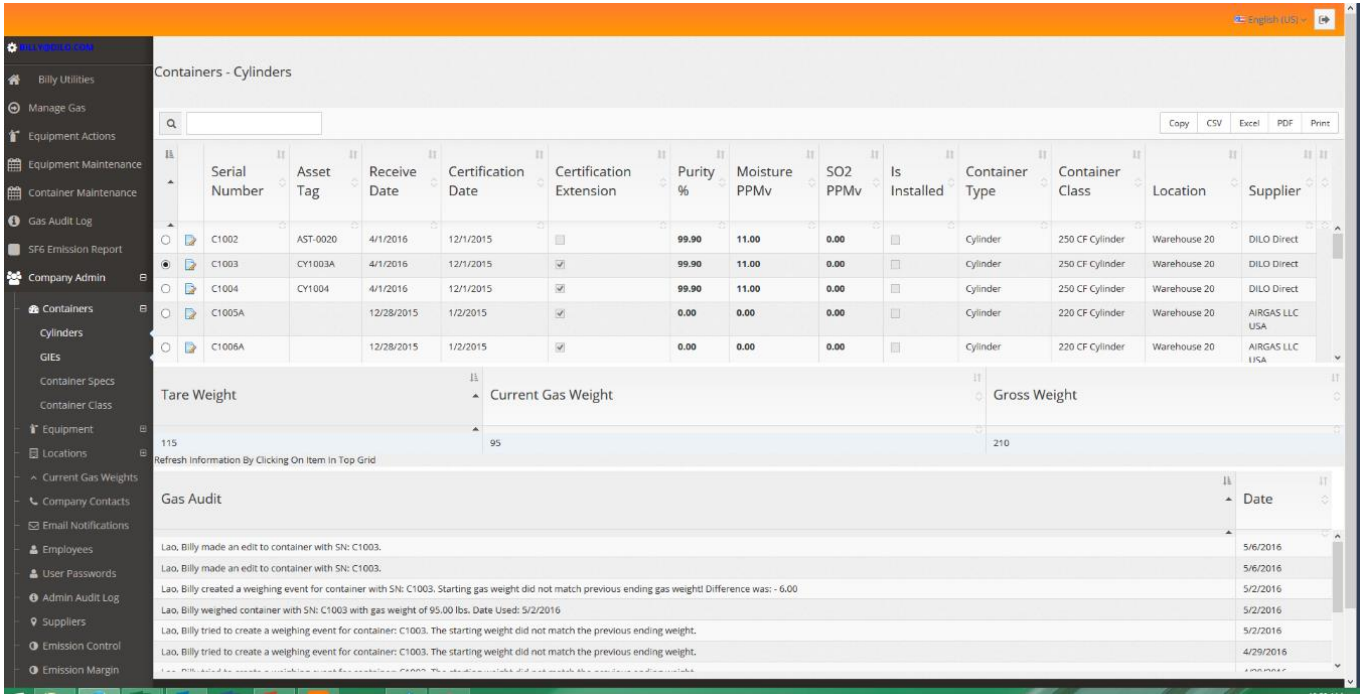
Tracking software solution

- Real time tracking
- Assist field lever personnel
- Simplifies EPA & CARB reporting
- Monitors GIE, cylinders *and* handling/measuring/weighing equipment

Necessary Changes to Minimize SF_6 Emission Tracking Problems

- Tracking should be in real-time
  - Will immediately alert personnel of potential problem (Incomplete recovery, nameplate issues, weighing issues)
- Improve work instructions
  - Field personnel needs detailed specs as opposed to “Remove SF6 from GIE”
    - A) Check and record temperature/density
      - Will immediately identify possible discrepancy with nameplate info
    - B) Stop recovery only after achieving blank-off pressure < 5 Torr
    - C) Record blank-off pressure
      - Will eliminate recovery emission and can be used to document nameplate inaccuracy
- Utilize highest accuracy weighing tools
  - Use mass flow scales whenever possible
    - Will eliminate discrepancies due to incorrect cylinder TW and residual SF_6 remaining in recovery equipment and hoses

Tracking software



What has worked

- GIE Nameplate
  - OEM's to provide measured SF6 amount when shipping with transport pressure
  - Eliminates most nameplate problems for newly installed GIE
- Cylinder tracking
  - Currently only using fleet of 500 SCE owned cylinders
  - New GIE shipped without gas
- Alerting field personnel to discrepancies
  - Example: Recovered SF6 doesn't match nameplate info
- Real-time emission rate reporting
- Immediate completion of EPA/CARB reports

Lessons learned & continuing challenges

- Importance of employee understanding / buy-in
- Added work for field personnel due to data entry
- System extremely helpful in identifying nameplate issues as well as handling errors immediately
- Having only SCE owned cylinders in system greatly simplifies processes
- Current emission rate and various inventories can easily be checked daily if needed
- Gas vendor can enter SF_6 purchases while shipments are in transit – inventories already updated when cylinders are received
- Tremendous time savings for both management as well as field level personnel

Thank you for your attention!

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