Modern SF₆ monitoring systems such as the ABB MSM offer solutions using best-in-class technologies. To provide a maximum value to the user it is important to also understand the limitations of these systems.

The excellent dielectric insulation and arc-quenching properties of sulfur-hexafluoride or SF₆ make it invaluable for the high-voltage switchgear industry. However SF₆ is also a greenhouse gas, over 20,000 times more potent than CO₂. Hence, accurate monitoring of SF₆ leakages become absolutely vital.

**Sensor technologies**

Leak detection algorithms require reliable sensor readings. There are two sensing technologies in use:

- separate gas pressure and temperature sensor readings followed by application of SF₆ equations of state &
- true gas-density monitors, which determine gas density via the natural frequency of an oscillator introduced into the gas system.

Both methods seek to eliminate the influence of temperature.

**Sensor accuracy**

High-end SF₆ pressure/density sensor manufacturers promise 1% typical accuracy full-scale (FS) and a maximum error of 1.8 % FS. The nature of this error may comprise offset error, gain error and/or drift. Gain errors have no impact on leak rate calculation because they drop out of the equations. Likewise offset errors have little impact. Drift errors, however would be very difficult to distinguish from a gradual gas density change. For this reason ABB utilizes sensors that are like a quartz-watch, drift-free. It shall be emphasized that the total effects of errors arising from sensor accuracy are significantly smaller than the ones imposed by temperature gradients (see next section).

**Temperature gradients**

Special challenges are variable temperature gradients within the gas compartment driven by both external environmental changes and load current cycles. Temperature gradients introduce a discrepancy between the density at the sensing point and the average gas density, adding further error to collected data. Special algorithms seek to eliminate this effect and are quite effective in case of radial temperature gradients caused by seasonal ambient temperature and load variations. Yet, the extremely high expectations of less than 0.5 % annual leakage for SF₆-filled apparatus remain very challenging to prove. If not for the special algorithms mentioned a density measurement series with a seasonal variation of 1% will cause an apparent leak rate of up to 6.28% (1% x 2π) which would certainly be unacceptable! Modern density trending software can reduce the effects of temperature gradients given sufficient time. It may be a year or two before annual seasonal variations can be largely compensated.

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**Partially indoor/outdoor compartments**
An indoor GIS inevitably needs to connect to an outdoor air-insulated substation (AIS). Some GIS compartments feed through the building walls and are therefore partially indoors/outdoors, resulting in an axial temperature gradient, i.e. along the axis of the compartment. Axial temperature gradients cause density gradients and distort the readings of true gas density sensor and pressure/temperature sensor combinations alike and therefore cause loss of information. A greater error margin has to be expected for these compartments as the lost information cannot be recovered without additional and cost-prohibitive sensing points on the same compartment.

**Small SF₆ filled compartments**
Each compartment in a gas-insulated switchgear substation (GIS) typically has the same seal lengths and number of sealing surfaces and access ports regardless of its size. Therefore, each compartment is likely to leak at nearly the same SF₆ mass flow rate. Hence smaller compartments, lose pressure/density quicker in the presence of equivalent leaks. Although greater individual leak rates when expressed as a percentage are to be expected with smaller compartments, they typically do not pose a problem, given proactive gas management, made easier via modern monitoring systems.

Total SF₆ loss divided by the total amount of SF₆ in the substation determines the overall environmental and economic impact from the substation. Ideally, this ratio should be less than 0.5 % per year.

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**Summary**
SF₆ gas trending is a powerful tool to ensure both the performance of SF₆ filled switchgear and protect the environment. As sensing technologies improve increasingly better accuracy will be achieved in combination with state-of-the art monitoring equipment. In the meantime it is critical to understand gas trending results in the context of short and long term accuracy limitations.

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