Optical technologies in the power industry: Monitoring and diagnosis of gas-insulated electrical switchgear
Outline

- Electrical switchgear and gas insulation
- Insulation gas diagnostics for SF$_6$
- Insulation gas diagnostics for SF$_6$-alternatives
Electrical Switchgear

- Essential components for energy transmission and distribution.
- Necessary at every switching point in the electrical power grid.
- Switching devices are associated with control, protection and metering of power systems.
Electrical Switchgear

- Air-insulated substations have large space requirement
- Significant reduction in footprint through use of potent insulation gases – the best is SF$_6$.
SF$_6$ as insulation gas

- During operation, the gas composition can change
  - Humidity ingress through seals and from outgassing
  - Arc-induced decomposition during switching
  - Partial discharge induced decomposition

- Decomposition products can be toxic and corrosive, and impede operability and safety of switchgear.

Partial discharge [image from www.think-grid.org]

SF$_6$ HV circuit breaker, M. Abrahamsson, ABB
Insulation gas diagnostics

- Permanent monitoring devices
  - Density and $T$-compensated pressure
  - Humidity
- Off-line, extractive devices
  - Humidity
  - Complete gas composition
- Leakage detection
Optical instruments for switchgear diagnosis

- SF₆ and many decomposition products offer IR signatures
- These are conveniently used for gas diagnostics

Wavenumber [cm⁻¹]

F. Rager, ABB
Commercial optical instruments for switchgear diagnosis

- Multi-component analysis
  - Gas composition analysis
  - Sampling & pump-back
- Integral leakage detection
  - Photoacoustic sensors
  - IR imaging

Innova-Lumasense

IR SF₆ analyzers, EMT

IR photoacoustic SF₆ analyzers, Innova-Lumasense
Alternatives to SF$_6$ are based on gas mixtures

Fluorinated organics (FOs) have high break-down strength

Performance of SF$_6$-alternatives strongly depends on composition

Composition is prone to change
  - Consumption in arc
  - Condensation
  - Other undesired processes,

New measurement instrumentation needed

Press Release

ABB achieves breakthrough in switchgear technology with eco-efficient insulation gas

New gas mixture offers alternative to SF6 and has potential to reduce carbon footprint of GIS by up to 50 percent – technology to be deployed in a Swiss pilot project.
Optical monitoring of SF$_6$-alternatives in switchgear

- Characteristic UV bands available for FOs
- UV LEDs available down to 200 nm with small bandwidth
- Can use straight-forward absorption measurement
Optical monitoring of SF$_6$-alternatives in switchgear

- Challenging measurement environment
  - Dust
  - Vibration
  - Corrosive gases
- Optical absorption measurement nevertheless viable
- Accuracy better than 1% of measured concentration

A. Kramer and M. Porus, ABB
Optical technologies are used widely for insulation gas diagnosis.

Diagnosis instrumentation is established for most aspects related to the use of SF\(_6\).

SF\(_6\)-alternatives require new solutions.
Power and productivity for a better world™