CONFERENCE: ALLSENSORS 2017, MARCH 19-23, 2017, NICE, FRANCE

Gas Sensing Technologies for the Electrical Power Industry

Challenges for eco-friendly next generation products

Axel Kramer, Sensor Technologies, ABB Corporate Research, Switzerland

Outline

ABB and its Corporate Research Centers

Trends and Drivers in Electrical Gas Insulation

Sensor technologies for gas diagnostics of conventional and novel eco-friendly insulation gas

Status of development (pilot installation, products) and future scenarios

Outline

ABB and its Corporate Research Centers

Trends and Drivers in Electrical Gas Insulation

Sensor technologies for gas diagnostics of conventional and novel eco-friendly insulation gas

Status of development (pilot installation, products) and future scenarios

ABB Key Figures

- 4 Divisions
- 135 000 employees

Key Figures 2015

in US $ unless otherwise stated

$36.4 bn
Orders received

$35.5 bn
Revenues

11.8%
Op. EBITA margin

$1.9 bn
Net income

$3.0 bn
Free cash flow

0.74 CHF
Dividend per share (Proposed)

Electrification Products

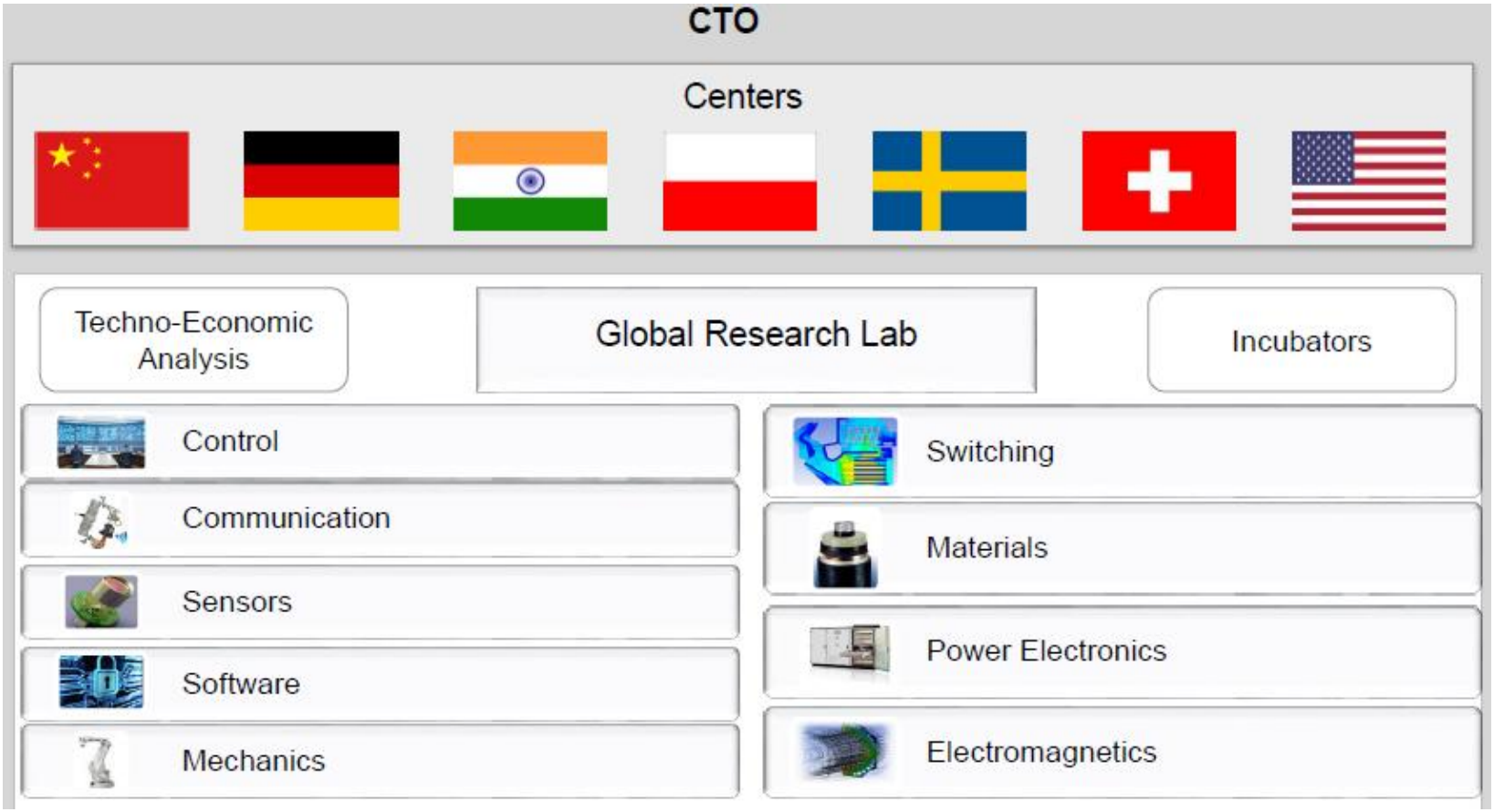
Robotics and Motion

Industrial Automation

Power Grids

ABB Corporate Research

Worldwide 7 research centers



Research Area: Sensors

Key research topics

Sensing technologies

Property Analysis

Measuring chemical properties and concentrations in gas, liquid or solid applications

Electrical Measurements

Measuring current and voltage in low, medium and high-voltage applications

Industrial Sensing

Measuring classical parameters (pressure, temperature, flow…) for process control & asset monitoring

Enablers and applications

Autonomous Devices

Energy harvesting and low-power technologies for truly autonomous devices

Machine Vision

Making robots and industrial equipment aware of the environment and easy to interact with

Electronics & Signal Processing

Electronics and embedded signal processing for smart and reliable devices

Outline

ABB and its Corporate Research Centers

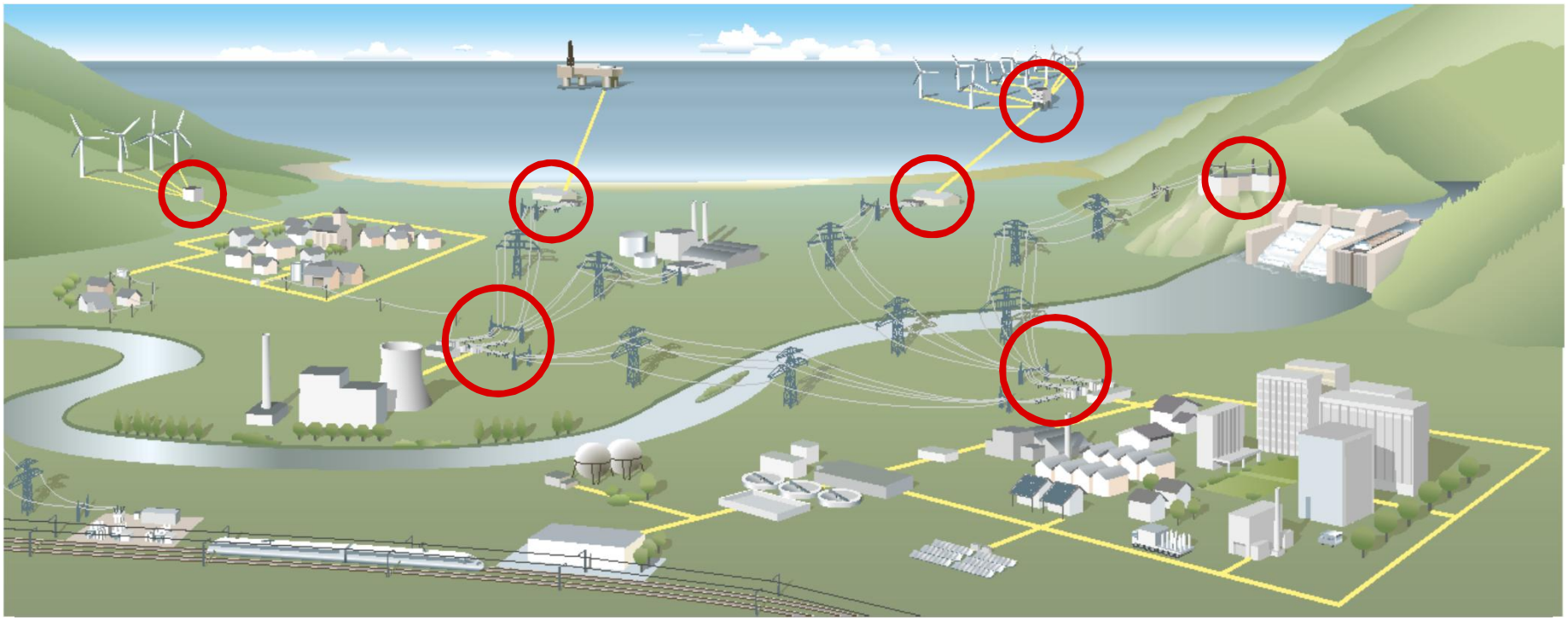
Trends and Drivers in Electrical Gas Insulation

Sensor technologies for gas diagnostics of conventional and novel eco-friendly insulation gas

Status of development (pilot installation, products) and future scenarios

High-power switching devices and lines

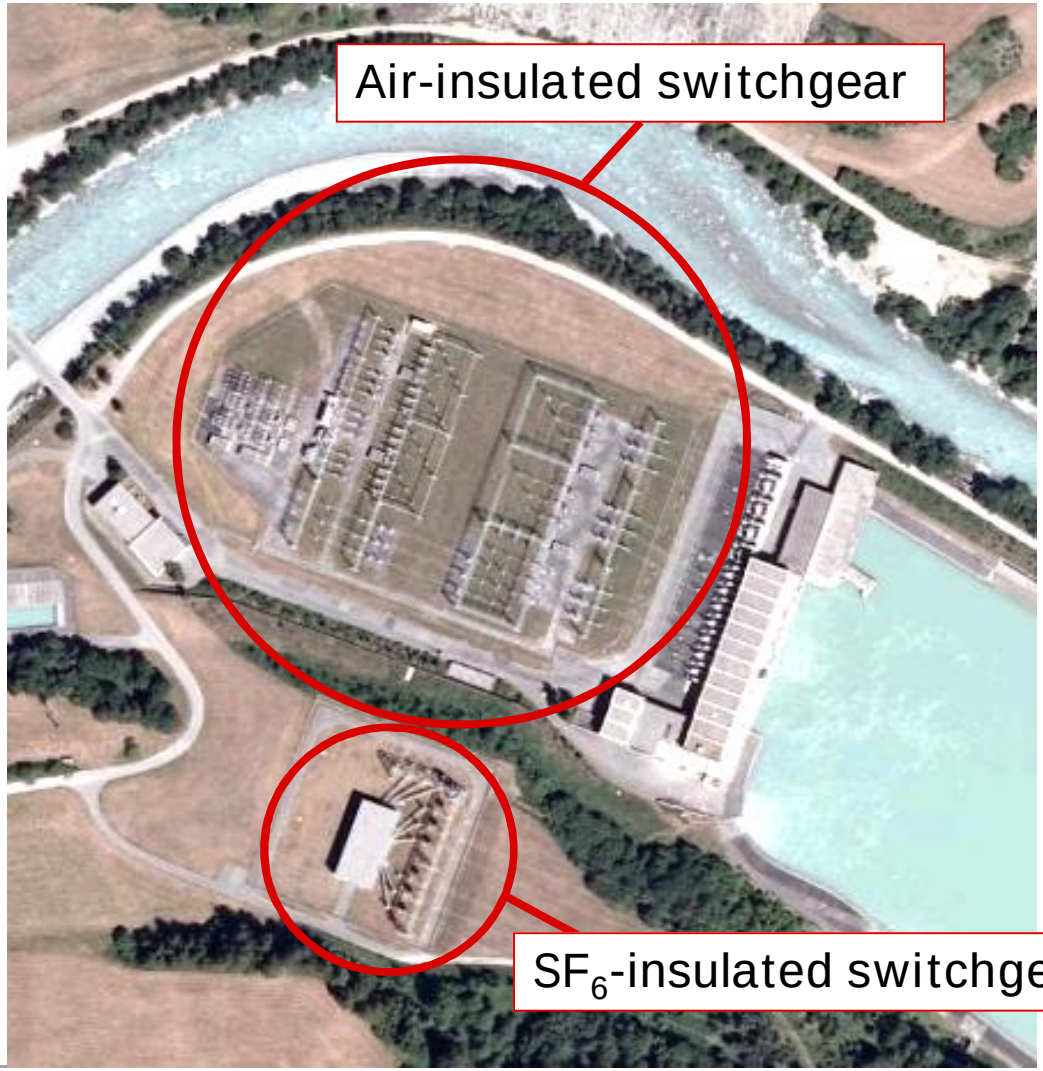
- Ø Essential components for energy transmission and distribution.
- Ø Switching devices are associated with control, protection and metering of power systems.
- Ø Necessary at every switching point in the electrical power grid.



Power product – Electrical Switchgear

- Air-insulated substations have large space requirement
- Significant reduction in footprint through use of potent insulation gases – the best is SF_6.

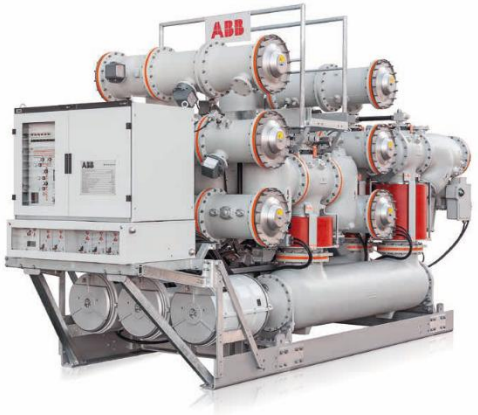
ABB's ELK-3 GIS

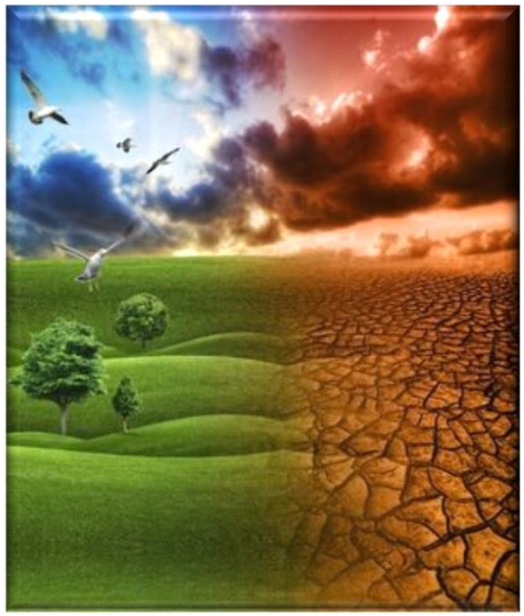


380kV GIS and AIS, Pradella CH

Environmantal Impact

- SF_6 is the best performing, multi-purpose gas for gas-insulated switchgear
- Only drawback: SF_6 exhibits extreme global warming potential
- One SF_6 molecule is equivalent to 23'000 CO_2 molecules
- Regulations and taxes for SF_6 already in place in some countries





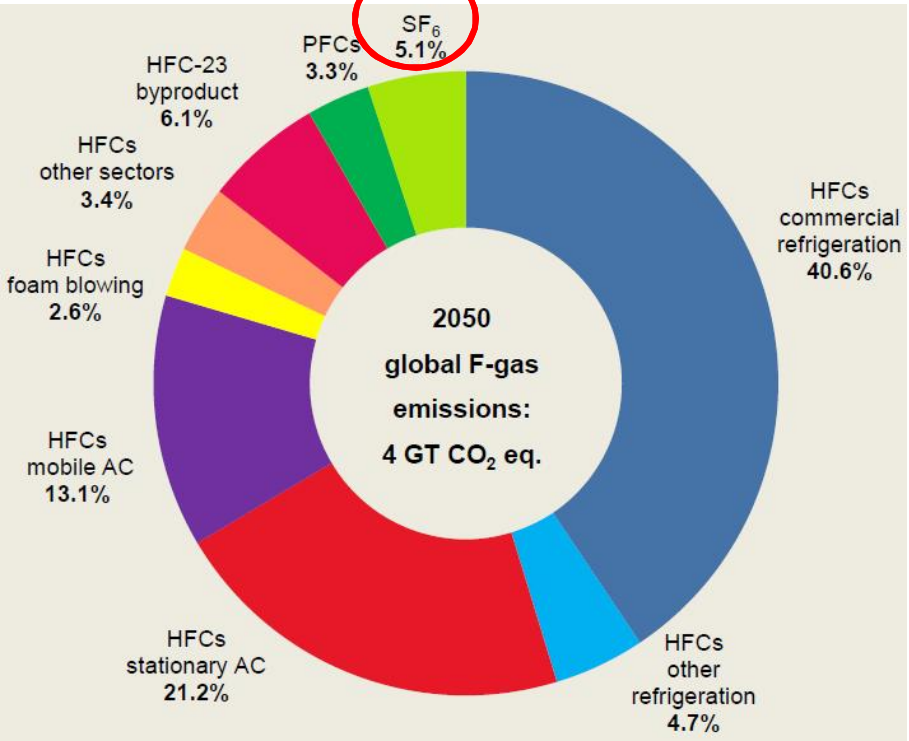
→ Research for SF_6 alternatives is required

Emission of fluorinated greenhouse gases

Projection for 2050

- F-gas contribution projection in 2050:
  4 GT/a (CO_2 eq.)
- Global annual CO_2 emission in 2014: 36 GT/a

- Governmental regulations are likely to come for SF_6
- Power industry is looking for SF_6 alternatives



Source: Gschrey et al., Greenhouse Gas Measurement & Management 1, 2011, p.85-92

Outline

ABB and its Corporate Research Centers

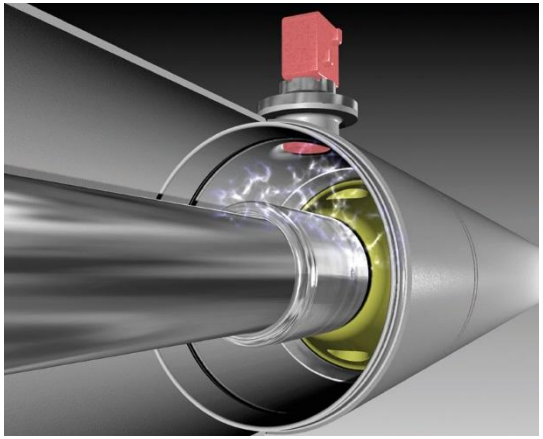
Trends and Drivers in Electrical Gas Insulation

Sensor technologies for gas diagnostics of conventional and novel eco-friendly insulation gas

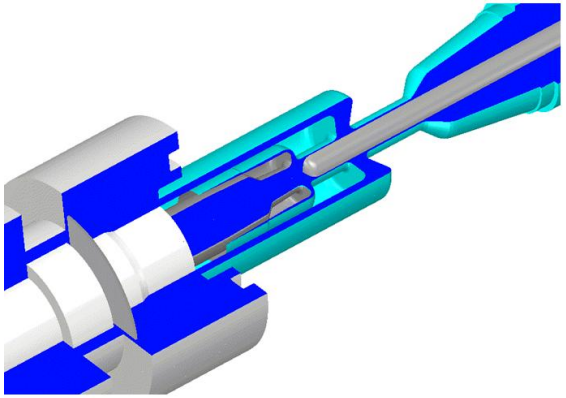
Status of development (pilot installation, products) and future scenarios

Sulfur hexafluoride SF_6 as electrical insulation gas

- Ø During operation, the gas composition can change
  - Ø Humidity ingress through seals and from outgassing
  - Ø Partial discharge induced decomposition
  - Ø Arc-induced decomposition during switching
- Ø 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
  - Humidity
  - Density and *T*-compensated pressure
- Off-line, extractive devices
  - Humidity
  - Complete gas composition
- Leakage detection

Humidity sensor on a GIS, Vaisala

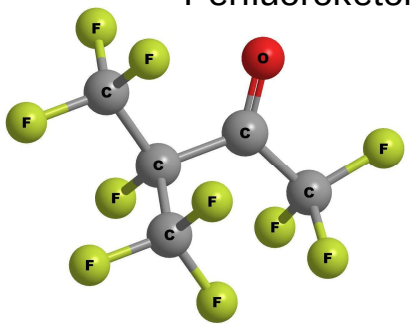
SF_6 sniffer, CPS

Optical chilled mirror dewpoint meter, MBW

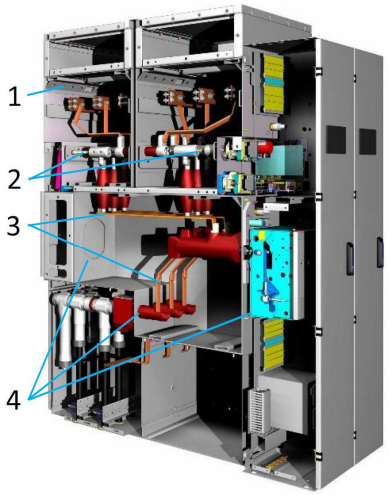
Gas analysis on a DTB, V. Williams, Company EMT

Novel eco-efficient insulation gas

Perfluoroketone



- Perfluoroketone (C5) + technical air (or CO_2/O_2)
- Test of gas mixture in a switchgear pilot installation in Zurich/Switzerland (since 2015)
- Product launch for MV-AirPlus GIS in July 2016



MV-Product

https://www.youtube.com/watch?v=bA11HkcJ0AY&feature=youtu.be

https://www.youtube.com/watch?v=JiXCZVIpY_s

ABB Annual Report 2015

Top innovations of 2015

Utilities

Lower environmental impact

ABB commissioned the world's first gas-insulated switchgear (GIS) with a new eco-efficient gas developed as an alternative to sulfur hexafluoride (SF_6). The new gas mixture, which has a global warming potential (GWP) almost 100 percent lower than that of SF_6, was developed with 3M.

Software improves asset management

Ellipse Select is a new enterprise software solution that helps customers to manage their assets more effectively through the life cycle and make better operational decisions, boosting both their performance and productivity. The solution illustrates ABB's unique ability to facilitate the convergence of operational and information technologies.

Industry

Mine of the future

ABB deployed its System 800xA automation platform to transform Boliden AB's Garpenberg lead, silver and zinc mine in central Sweden into one of the world's most efficient and productive mines. Autonomous processes stretching a kilometer underground are unified in a single system driving efficiency and productivity to the next level.

First truly collaborative robot

YuMi, the first truly collaborative robot, was introduced to the market at Hanover Fair. Designed for a new era in manufacturing, where robots and humans work side-by-side on the same tasks, YuMi is flexible and dexterous. It can be integrated into production lines without the need to redesign the space.

Analyzers for gas concentration measurement

Gas composition tracking and diagnosis

Why is knowledge of gas composition required?

- Insulation performance is a function of gas concentration
- Dew point of gas is determined by partial pressure (i.e., concentration)

→ For stable and safe operation of the electrical apparatus

When is measurement necessary?

- factory testing (test fillings and type tests)
- during commissioning (i.e. filling of equipment)
- tracking (for breakers where gas is consumed)
- service (asset condition assessment)
- during de-commissioning (hazard assessment)

Development of three novel types of analyzers

Inhouse Development

p-*T*-ρ analyzer

- Non-specific analyzer
  - Based on *p*-*T*-ρ measurement

  (Applied for non-aged gas mixture)

LED analyzer

- Specific analyzer
  - UV-LED based optical absorption analyzer for fluoroketone analysis
  - Laser-based optical absorption analyzer for fluoroketone and humidity analysis

  (Applied for non-aged and aged gas mixtures)

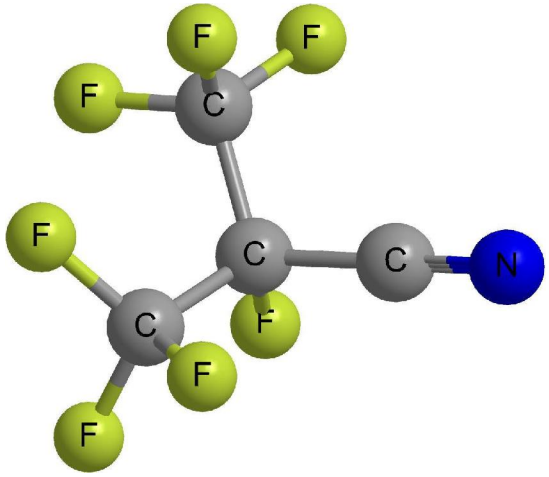
Competitors – General Electrics

Insulation gas and analyzer solutions

g3 - green gas for grid

Developed by Alstom/GE and 3M

Based on gas mixture of fluoronitrile [$(CF_3)_2CFCN$] and CO_2



Novec-4710
(Fluoronitrile)

GE assigned WIKA to develop a gas analyzer for fluoronitrile

Outline

ABB and its Corporate Research Centers

Trends and Drivers in Electrical Gas Insulation

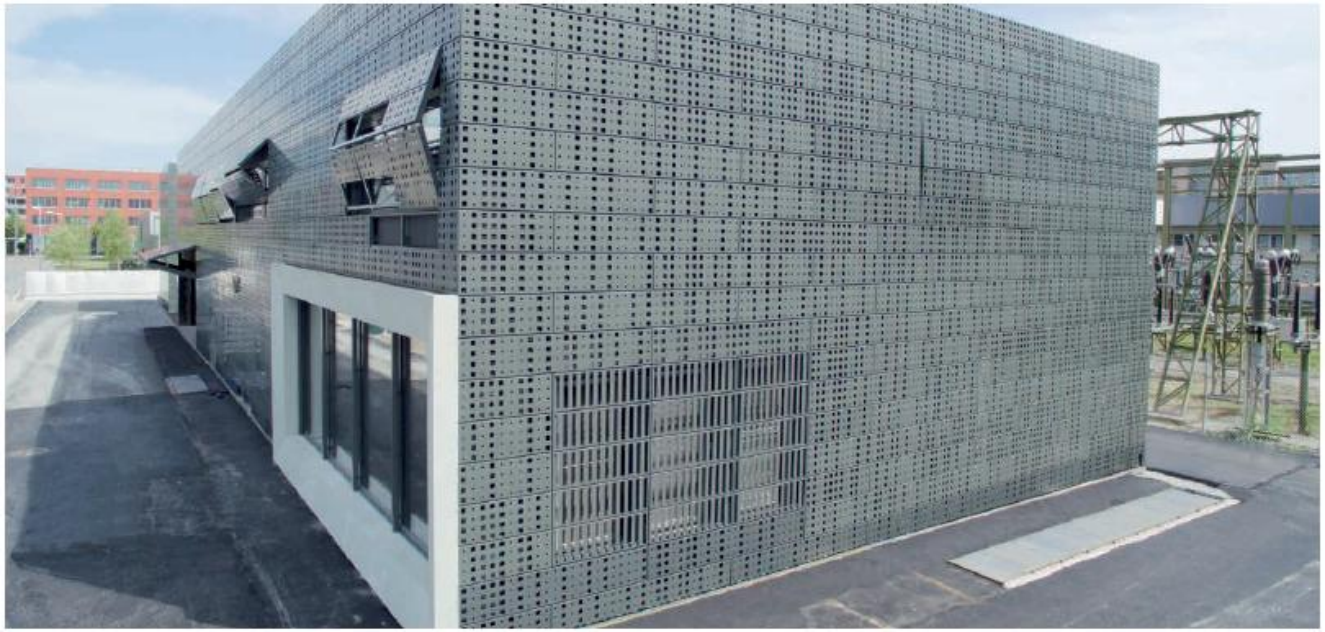
Sensor technologies for gas diagnostics of conventional and novel eco-friendly insulation gas

Status of development (pilot installation, products) and future scenarios

Pilot installation with eco-friendly insulation gas

Press release: August 2015

World's first gas-insulated switchgear (GIS) installation with new eco-efficient gas mixture
ewz Oerlikon substation, Switzerland



Pilot installation with eco-friendly insulation gas

Eco-efficient gas mixture in Swiss utility (EWZ, Zurich)

- World's first HV and MV gas-insulated switchgear (GIS) installation with new eco-efficient gas mixture

Pilot installation with eco-friendly insulation gas

Eco-efficient gas mixture in Swiss utility (EWZ, Zurich)

- World's first HV and MV gas-insulated switchgear (GIS) installation with new eco-efficient gas mixture (2015)

- Product launch for MV-AirPlus GIS in July 2016

Pilot installation with eco-friendly insulation gas

Eco-efficient gas mixture in Swiss utility (EWZ, Zurich)

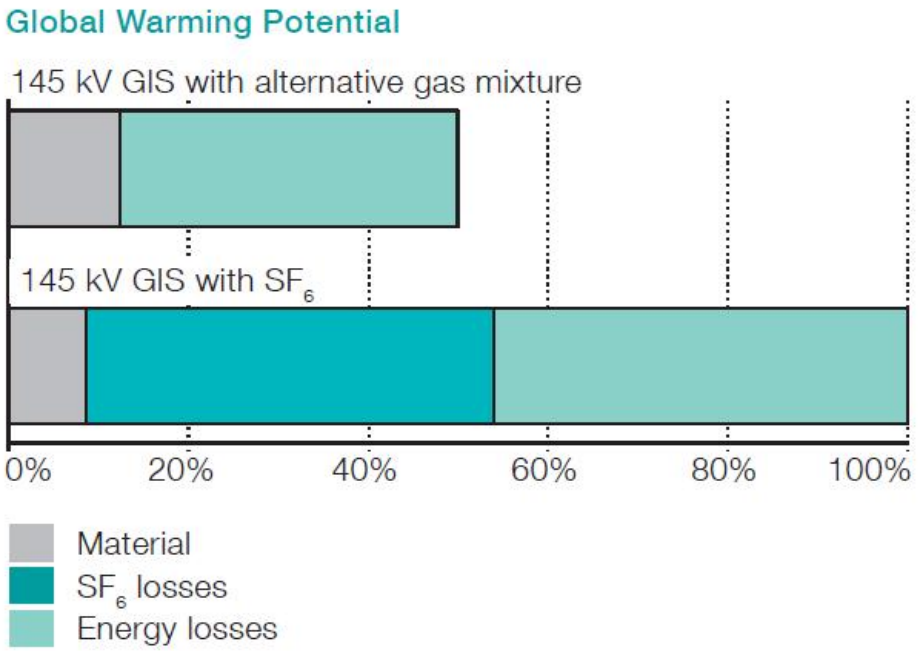
Advantages:

- GWP of new gas mixture is almost 100% lower than GWP of SF_6
- Regulatory procedures for SF_6 such as maintaining inventory, special requirements in gas handling, filling and decommissioning of the equipment will be avoided
- Savings can be made in SF_6 related taxes which are applicable in some countries
- The new gas mixture is the only one available so far that has been type tested according to IEC standards which meets performance criteria and has a GWP <1

Pilot installation with eco-friendly insulation gas

Eco-efficient gas mixture in Swiss utility (EWZ, Zurich)

CO_2 emissions can be halved over the life cycle of a GIS (30 years):



Pilot installation with eco-friendly insulation gas

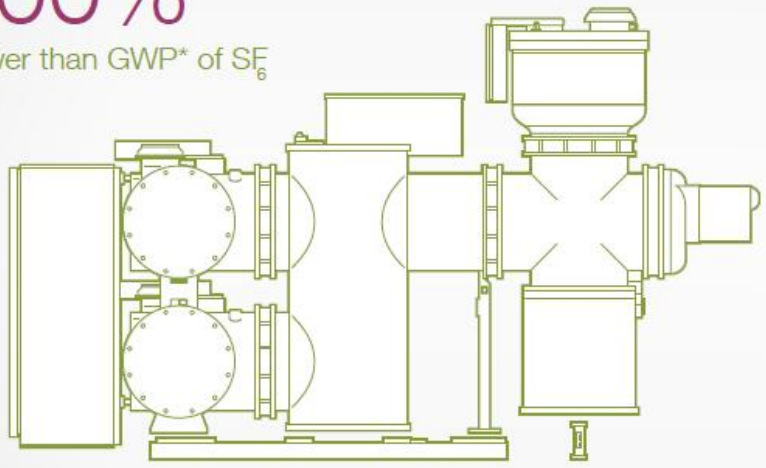
Eco-efficient gas mixture in Swiss utility (EWZ, Zurich)

CO_2 savings calculated in units of cars:

Global warming potential (GWP)
of new gas mixture is almost

100%

lower than GWP* of SF_6



Equipment in pilot substation includes:
- 8 bays of 170 kV GIS
- 50 panels of 24 kV GIS

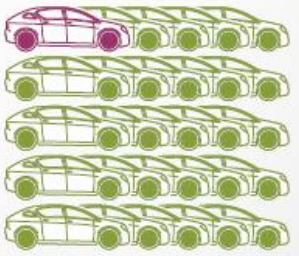
CO_2

CO_2 equivalent reductions with the new gas equate to taking

25 cars

off the road

(based on a lifecycle of 30 years for the pilot GIS installation and cars running 15,000 km per year)

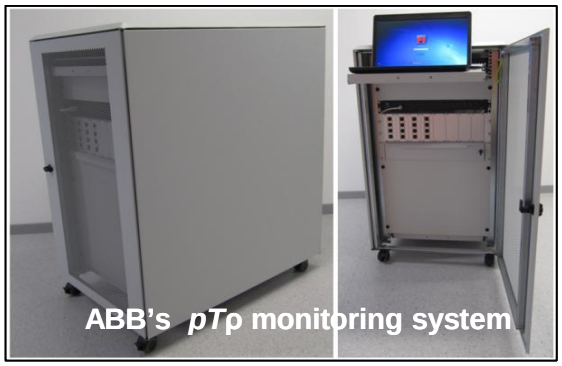


(*The GWP describes how much heat a greenhouse gas traps in the atmosphere.)

Sensor application in utility pilot installation

Eco-efficient gas mixture in Swiss utility (EWZ, Zurich)

Pilot substation is equipped with *pTρ*-sensors and a mobile system tracking 9 compartments of a GIS (filled with a novel eco-efficient gas mixture)



Inhouse application of analyzer

Characterization of filling/mixing equipment

- UV-LED analyzer was applied to characterize the output concentration of a system that injects pre-mixed insulation gas.
- Set concentration (4% of fluoroketone) was verified within an uncertainty of 0.04%-points.
- Robust and field-applicable sensor instrumentation for AirPlus is available.

Summary

ABB is a driver for environmentally friendly soultions
(here shown using the example of novel electrical insulation gas)

Technology development driven by Corporate Research

Sensor systems required to diagnose operational status of device

Competitors also work on similar solutions

Stricter standards and regulations for SF_6 are expected soon, leveraging the novel eco-friendly solution