Medium-voltage gas insulated switchgear
Technologies for a smarter and greener network
Technical session
Medium-voltage gas insulated switchgear

- Part 1
  Speaker / title
  Lukas Vogels /
  Global Product Marketing Manager MV Primary Switchgear /
  Ratingen - Germany

- Part 2
  Speaker / title
  Giuseppe Arnetti /
  Global Product Marketing Manager MV Secondary Switchgear /
  Dalmine - Italy
Society having higher demands on power distribution
Challenges in today’s energy sector

- World’s increasing demand of power & increasing urbanisation
- Balance big investments on electrical distribution infrastructure with environmental concerns
- Grid reliability & space utilization
Overview of this session

This session addresses how MV GIS supports the key aspects:

- Part 1: Further improving the environmental footprint
- Part 2: Smart technologies to maximize grid reliability
- Questions and answers
Medium-voltage gas insulated switchgear
Part 1
Technology leap – Eco-efficient GIS
Eco-efficient switchgear technology

Introduction

- Switchgear history and trends
  - Challenges and future requirements
  - Insights on eco-efficient alternatives to SF$_6$
  - ABB's answer to the climate challenge
- Summary
- Questions and answers
Switchgear history and trends
Air-insulation switchgear (AIS)

Switchgear from 1910
- No operator safety
- Huge dimensions
- Low reliability

Todays' air-insulated switchgear (AIS)
- Increased personal safety
- Reduced dimensions
- Higher reliability
Switchgear history and trends
Comparison of AIS and GIS switchgear technologies

Gas-Insulated switchgear with $\text{SF}_6$
- $\text{SF}_6$ insulates 3x better than air
- Independent from environment conditions

<table>
<thead>
<tr>
<th>AIS</th>
<th>GIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact</td>
<td>Very compact</td>
</tr>
<tr>
<td>High reliability</td>
<td>Highest reliability</td>
</tr>
<tr>
<td>High safety</td>
<td>Maximum safety</td>
</tr>
<tr>
<td>Low maintenance</td>
<td>Maintenance-free</td>
</tr>
</tbody>
</table>
Switchgear history and trends
ABB as pioneer in gas-insulated switchgear (GIS)

1967: World's first GIS switchgear
- High-voltage 170kV
- Swiss utility ewz, Zurich

1984: First medium-voltage GIS with 3-phase encapsulation (ZV2)

1994: First medium-voltage GIS without gas-works at site (ZX1)

2015
First high- and medium-voltage GIS with alternative gas
Challenges and future requirements
Why has SF$_6$ been such a success?

- Electrical performance
- Thermal properties
- Inert and self-healing
- Non-toxic
- Easy handling

High global warming potential (GWP 22,800)
Switchgear history and trends
Sustainability in current ABB MV-GIS portfolio

- Continuous supervision of gas density
- End of life recycling
- Factory-filling of Insulation gas
- No gas-handling at site
- Busbar and cable plug technology
Challenges and future requirements

Global warming as driver

- Increased environmental awareness and emphasis on green solutions
- Climate change policies
  - 1997: Kyoto protocol signed
  - 2006: EU regulation on fluorinated greenhouse gases
  - SF₆ reporting obligation and taxation in certain countries
- 2010: New promising fluids are developed
  ABB starts research of application
Challenges and future requirements
Alternatives need to fulfill various criteria

- Possible alternative needs to meet a lot of requirements:
  - Climate impact
  - Technical performance
  - Stability and operating conditions
  - Safety and handling

- Although research has been ongoing over decades, still no 1-to-1-replacement for SF6 is known
Research on eco-efficient alternatives to $\text{SF}_6$

Extensive research on various options

Years of extensive research
- ABB Corporate Research Centers
- External partners

Evaluation criteria
- Global warming potential (GWP)
- Dielectric properties & compactness
- Material compatibility
- Self-healing insulation
- Toxicity & flammability
- Recycling & sustainability
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Research on eco-efficient alternatives to SF$_6$

**Dry air and N$_2$**

<table>
<thead>
<tr>
<th>Evaluation</th>
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<th>N$_2$</th>
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<tbody>
<tr>
<td>Global warming potential (GWP)</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Dielectric properties &amp; compactness</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Material compatibility</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Self-healing insulation</td>
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<td>+</td>
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<tr>
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- Dry air has slightly better dielectric performance than N$_2$
- Pure N$_2$ does not contain O$_2$, so better material compatibility than air
- **Dielectric performance limited, but solution for lower voltages**

Composition of air:
- 78% N$_2$
- 21% O$_2$
- 1% other

Pure nitrogen: 100% N$_2$
Research on eco-efficient alternatives to SF₆

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Evaluation criteria
- Global warming potential (GWP)
- Dielectric properties & compactness
- Material compatibility
- Self-healing insulation
- Toxicity & flammability
- Recycling & sustainability
Research on eco-efficient alternatives to SF$_6$
Solid insulation

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- Not self-healing, no repair possible (partial discharge)
- No recycling possible, energy intensive production

→ No reliable and sustainable solution for ABB
Research on eco-efficient alternatives to SF$_6$

Extensive research on various options

Years of extensive research
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Evaluation criteria
- Global warming potential (GWP)
- Dielectric properties & compactness
- Material compatibility
- Self-healing insulation
- Toxicity & flammability
- Recycling & sustainability
Research on eco-efficient alternatives to SF$_6$
SF$_6$ mixes with N$_2$

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- Still rather high GWP
- Recycling of gas mixture difficult

→ No eco-efficient solution
Research on eco-efficient alternatives to SF$_6$

Extensive research on various options

Years of extensive research
- ABB Corporate Research Centers
- External partners

Evaluation criteria
- Global warming potential (GWP)
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Research on eco-efficient alternatives to SF$_6$
Nitriles mix with air

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- Technical performance close to SF$_6$
- GWP still in range of 1.000

➔ No real eco-efficient solution
Research on eco-efficient alternatives to SF$_6$

Extensive research on various options

**Years of extensive research**

- ABB Corporate Research Centers
- External partners

**Evaluation criteria**

- Global warming potential (GWP)
- Dielectric properties & compactness
- Material compatibility
- Self-healing insulation
- Toxicity & flammability
- Recycling & sustainability
Research on eco-efficient alternatives to SF$_6$

Ketones mix with air

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- Very low GWP < 1
- Technical performance close to SF$_6$

→ **Technically and environmental-friendly best alternative**
Identified "Low GWP" alternatives:

GWP = 0:
- Dry Air and N₂ are possible candidates
- Dry Air has better performance than N₂

GWP > 0:
- Ketones and Nitriles close to SF₆ performance
- Ketones much lower GWP than Nitriles

<table>
<thead>
<tr>
<th></th>
<th>GWP *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ketones / Air mix</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Nitriles / Air mix</td>
<td>1.500 - 2.000</td>
</tr>
</tbody>
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* for MV GIS applications
Research on eco-efficient alternatives to SF$_6$

ABB's two eco-efficient insulation gases

Two technologies with GWP <1

- Alternative to SF$_6$ shall have minimal GWP
  - **Dry Air** for lower voltage ratings, GWP 0
  - **AirPlus Ketones/air mix** for higher ratings, GWP <1

New **Ketones** gas mixture achieves close to 100% reduction of GWP;
  **Dry Air** has NO GWP
Research on eco-efficient alternatives to SF\textsubscript{6}
Details on ABB's two eco-efficient insulation gases

**DryAir technology**
- Dry Air is technical air with a limited amount of water.
- The technical performance limits the use of Dry Air in MV applications to the 12 kV range without increasing switchgear dimension.

**AirPlus technology**
- New gas mixture consisting of DryAir (N\textsubscript{2}, O\textsubscript{2}) with Perfluoro Ketones (C5 FK).
- Pure gas of C5 FK has much better dielectric strength than SF\textsubscript{6}. Dielectric strength of mixture close to SF\textsubscript{6}.
- C5 FK has boiling point of 25°C, but high vapor pressure. When mixed with carrier gas, stays gaseous for temperature range of indoor switchgear.
- If gas used for current breaking (i.e. HV): CO\textsubscript{2} can be added to the mixture.
ABB's eco-efficient switchgear
Eco-efficient products for primary distribution

ZX2 Primary GIS
- Pilot 1: ewz, Zurich, Switzerland
  - 50 panels 24 kV with AirPlus ketone technology
  - Switchgear commissioned in June 2015
- Pilot 2: Germany
  - 8 panels 24kV with AirPlus ketone technology
  - Switchgear installed in Jan 2016
ABB's eco-efficient switchgear
Eco-efficient products for secondary distribution

SafeRing Secondary GIS (RMU)

- **SafeRing AirPlus** pilots
  - SafeRing 24kV with Ketone technology
  - First units delivered in Sep 2015

- **SafeRing Air** product 12kV already available
  - Available since 2013 in Northern European countries
  - Now launched for other regions
ABB's eco-efficient switchgear
ABB continues writing history in GIS technology

1967: World's first GIS switchgear
High-voltage 170kV

1994: First medium-voltage GIS
without gas-works at site

1984: First medium-voltage GIS
with 3-phase encapsulation

2015: World's first MV & HV
GIS with eco-efficient gases
Eco-efficient switchgear technology
Summary and key messages

ABB eco-efficient switchgear

- Combining reliability, safety and compactness of traditional GIS with environmental sustainability
- New technology is an alternative for SF\(_6\), not a replacement
- ABB is currently completing eco-efficient switchgear portfolio. First products planned for end of 2016

![Chemical structures of SF\(_6\), AirPlus, and Dry Air]

<table>
<thead>
<tr>
<th>SF(_6)</th>
<th>AirPlus</th>
<th>Dry Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>22'800</td>
<td>&lt;1</td>
<td>0</td>
</tr>
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New **Ketones** gas mixture achieves close to 100% reduction of GWP; **Dry Air** has 0 GWP
Medium-voltage GIS portfolio
Part 2
Smart secondary distribution switchgear
Society having higher demands on power distribution
Benefits of smart grids

- Increase distribution network reliability and quality by providing fast fault location, isolation and restoration.
- Enable integration of renewable sources into Power Networks
- A smarter grid will provide greater control over energy costs and a more reliable energy supply for consumers.
Transmission and distribution grids
Present situation

Traditional Automation Areas
- Distribution Control Centers
  - Network management SCADA/DMS
  - Outage Management
  - Workforce management
- Primary Substation Automation
  - Integrated Protection, Control and Monitoring
Transmission and distribution grids
Focus on secondary distribution

New Automation Areas

- **Secondary Distribution - MV Network**
  - Fault Passage Indication
  - Monitoring of Voltages and Currents
  - Remote Control of switches
  - Selective Protection with breakers

- **Secondary Distribution - LV Network**
  - Intelligent breakers for protection and control of the LV grid
  - Smart meters with fault indication capabilities

- **Asset Management**
  - On-line Condition Monitoring
# Solutions for smart secondary distribution

The right grid automation level to meet your needs

<table>
<thead>
<tr>
<th>LEVEL 1</th>
<th>LEVEL 2</th>
<th>LEVEL 3</th>
<th>LEVEL 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MONITORING</strong></td>
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</tr>
<tr>
<td>Situation Awareness</td>
<td>Fault Isolation</td>
<td>Power Flow Measurement</td>
<td>Protection Selectivity</td>
</tr>
<tr>
<td>• Indication of Switch status</td>
<td>• Remote control of Switches</td>
<td>• High accuracy measurement (V,I,P,Q,f)</td>
<td>• Directional O/C and E/F protect.</td>
</tr>
<tr>
<td>• Fault passage Indication (FPI)</td>
<td>• Remote network Configuration</td>
<td></td>
<td>• Protect. Interlocking by GOOSE</td>
</tr>
<tr>
<td>• LV Measurements</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>• Condition Monitoring</td>
<td></td>
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</table>

**Functions**

- Situation Awareness
  - Indication of Switch status
  - Fault passage Indication (FPI)
  - LV Measurements
  - Condition Monitoring

- Fault Isolation
  - Remote control of Switches
  - Remote network Configuration

- Power Flow Measurement
  - High accuracy measurement (V,I,P,Q,f)

- Protection Selectivity
  - Directional O/C and E/F protect.
  - Protect. Interlocking by GOOSE

**Devices**

- Wireless Gateway
  - ARR600

- Wireless Controller
  - ARC600

- IED
  - REC615
Solutions for smart secondary distribution
Situation awareness

Functions

- Indications of switch status
- Fault passage indication (FPI)
- LV Measurements
- Condition Monitoring

Benefits

- Fault Location
- Voltage Stability even with intermittent distributed generation
- Reduce Maintenance cost
Solutions for smart secondary distribution
Fault isolation

Functions
- Remote Control of switches
- Remote network configuration

Benefits
- Centralized fault isolation and restoration with reduction of the time of outages
- Increase network efficiency
Functions

- High accuracy Measurements V, I, P, Q, f

Benefits

- Voltage Stability even with intermittent distributed generation
- Increase network efficiency
Solutions for smart secondary distribution

Protection selectivity

Functions

- Directional overcurrent and earth fault protection
- Reclosing for overhead lines
- Protection interlocking

Benefits

- Reduced number of outages
L4 Solution example
Logic selectivity in closed loop

Operate Delay: 300ms
L4 Solution example
Logic selectivity in closed loop

Primary Switchgear A

Primary Switchgear B

Operate protection block when same Over Current direction

Operate Delay: 300ms

GOOSE

Circuit Breaker ON

Over Current Direction
L4 Solution example
Logic selectivity in closed loop

Operate protection enable when different over current direction

Operate Delay: 300ms

Circuit Breaker ON

Over Current Direction
L4 Solution example
Logic selectivity in closed loop

Primary Switchgear A
Operate Delay: 300ms

Primary Switchgear B

Fault isolation <200ms

Circuit Breaker ON
Circuit Breaker OFF
Over Current Direction
ABB’s Grid Automation products and solutions
Optimal solution for entire value chain
Medium Voltage Products
MV GIS portfolio full range of offering

Medium-voltage gas insulated secondary distribution switchgear portfolio

- Safering /Safeplus
  - Gas Insulated Indoor Switchgear / RMU
  - Available up to 40,5kV

- Safelink CB
  - Gas Insulated Outdoor Switchgear
  - Available up to 17,5kV

- Safelink 2
  - Gas Insulated Outdoor Switchgear
  - Available up to 17,5kV

- A complete and comprehensive portfolio across all segments.
- Arc Fault contained switchgear design
- Global Portfolio with local value customization to meet market demand

Enabling a stronger and smarter power network
Medium Voltage Products
MV GIS portfolio full range of offering

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  - Gas Insulated Outdoor Switchgear
  - Available up to 17,5kV

- Suitable for breaker and switch Fuse applications
- Front Cable termination access
- Modular and RMU solutions available

Enabling a stronger and smarter power network
Medium Voltage Products
MV GIS portfolio full range of offering

Medium-voltage gas insulated secondary distribution switchgear portfolio

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- Safelink 2
  - Gas Insulated Outdoor Switchgear
  - Available up to 17,5kV

- Suitable for Circuit Breaker application
- Extendible / Non-Extendible solutions
- Side and Rear Cable termination access

Enabling a stronger and smarter power network
Medium Voltage Products
MV GIS portfolio full range of offering

Medium-voltage gas insulated secondary distribution switchgear portfolio

- Suitable for Switch Fuses application
- Ultra compact solution for new and replacement installations with space constraints
- Outdoor / Indoor solutions available

Safering / Safeplus
Gas Insulated Indoor Switchgear / RMU
Available up to 40,5kV

Safelink CB
Gas Insulated Outdoor Switchgear
Available up to 17,5kV

Safelink 2
Gas Insulated Outdoor Switchgear
Available up to 17,5kV

Enabling a stronger and smarter power network
Take away from this session

Medium-voltage gas insulated portfolio – implementing the future already today

- Products and solutions in place to support modern Power Distribution infrastructure
- ABB resources and Laboratories available to support assessment, justification, project planning and execution
- Smart solutions, from refurbishing existing secondary substations and adding wireless communication, to turnkey switch, automation and communication systems
- Even MV-GIS itself, which represents the highest level of availability is brought to the next level through use of the new eco-efficient insulation gas: AirPlus based on Fluoroketones.

ABB Medium-voltage gas insulated switchgear - new technologies for a smarter and greener network
Power and productivity for a better world™