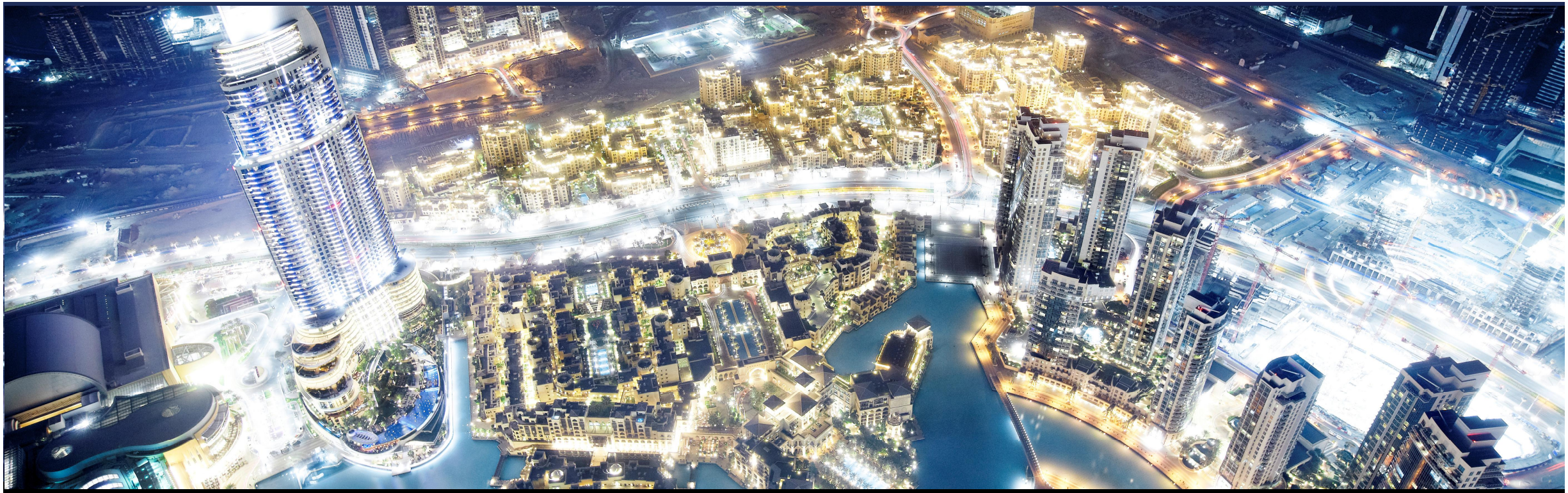


ABB Medium Voltage Days MEA 2016

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

Power and productivity
for a better world™

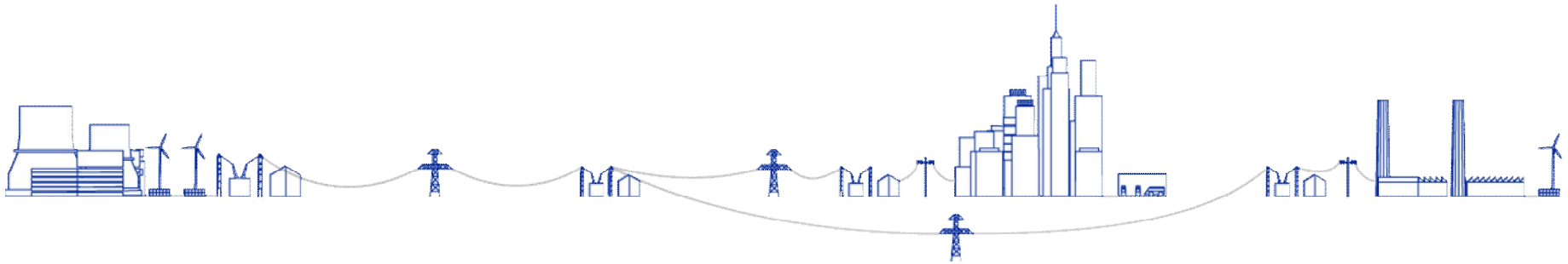
Technical session
Medium-voltage gas insulated switchgear

- 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

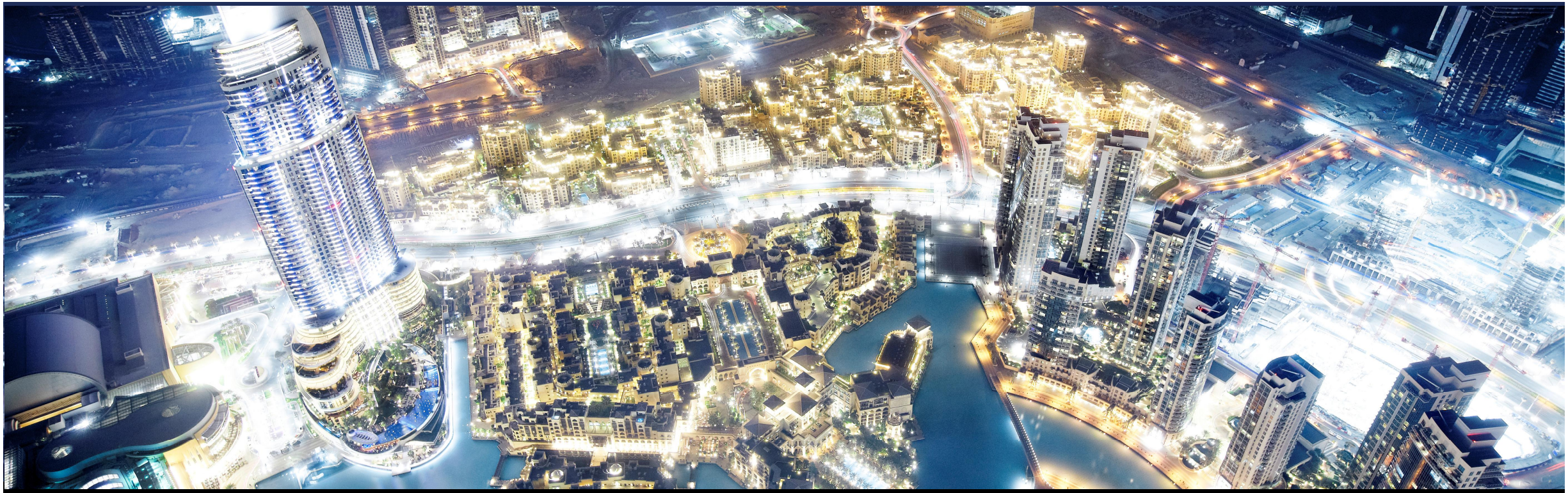


ABB Medium Voltage Days MEA 2016

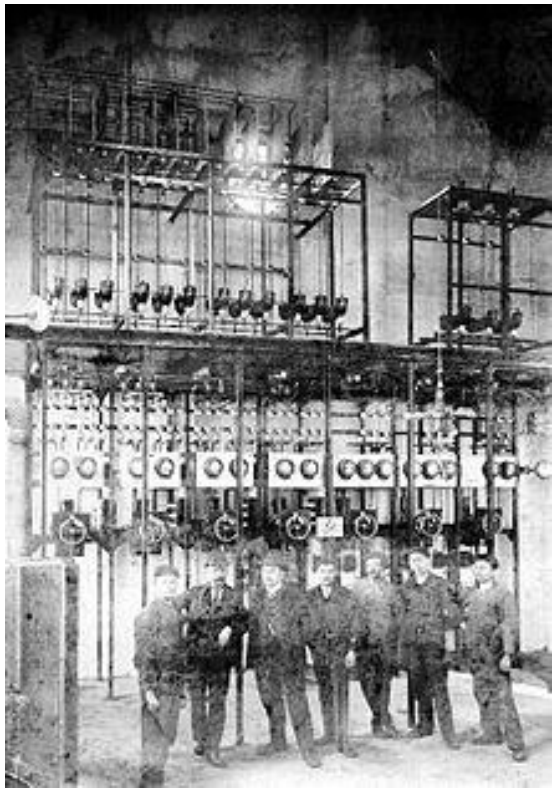
Medium-voltage gas insulated switchgear
Part 1
Technology leap – Eco-efficient GIS

Power and productivity for a better world™

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)



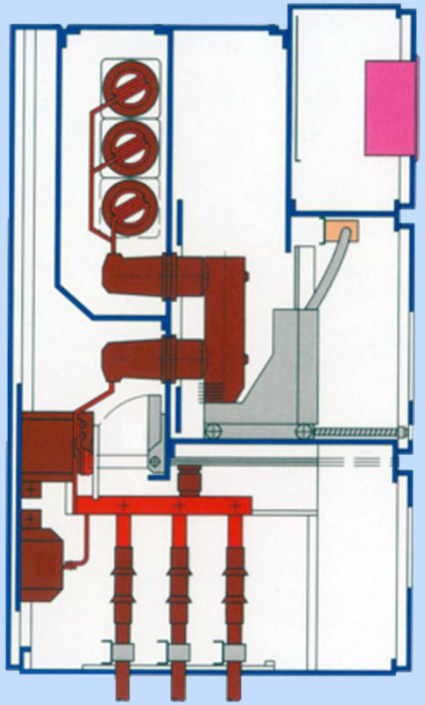
Switchgear from 1910

- No operator safety
- Huge dimensions
- Low reliability

Todays' air-insulated switchgear (AIS)

- Increased personal safety
- Reduced dimensions
- Higher reliability

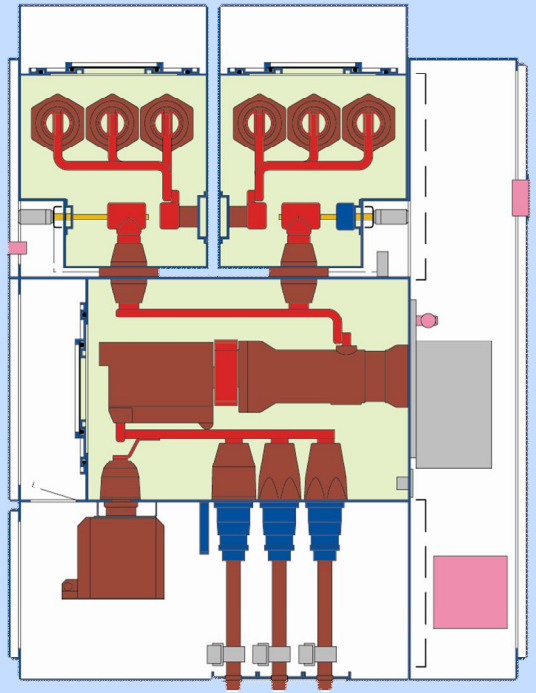
Switchgear history and trends
Comparison of AIS and GIS switchgear technologies



Gas-Insulated switchgear with SF_6

- SF_6 insulates 3x better than air
- Independent from environment conditions

AIS	GIS
Compact	Very compact
High reliability	Highest reliability
High safety	Maximum safety
Low maintenance	Maintenance-free



Switchgear history and trends
ABB as pioneer in gas-insulated switchgear (GIS)

1967: World's first GIS switchgear

- High-voltage 170kV
- Swiss utiliy 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?

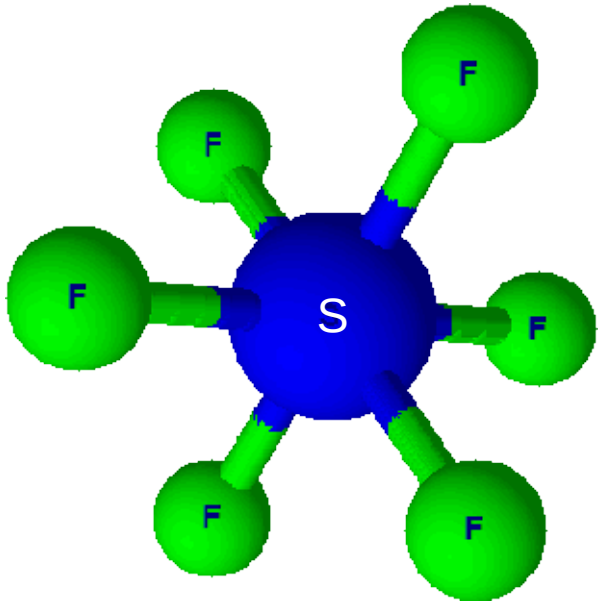
Electrical performance

Thermal properties

Inert and self-healing

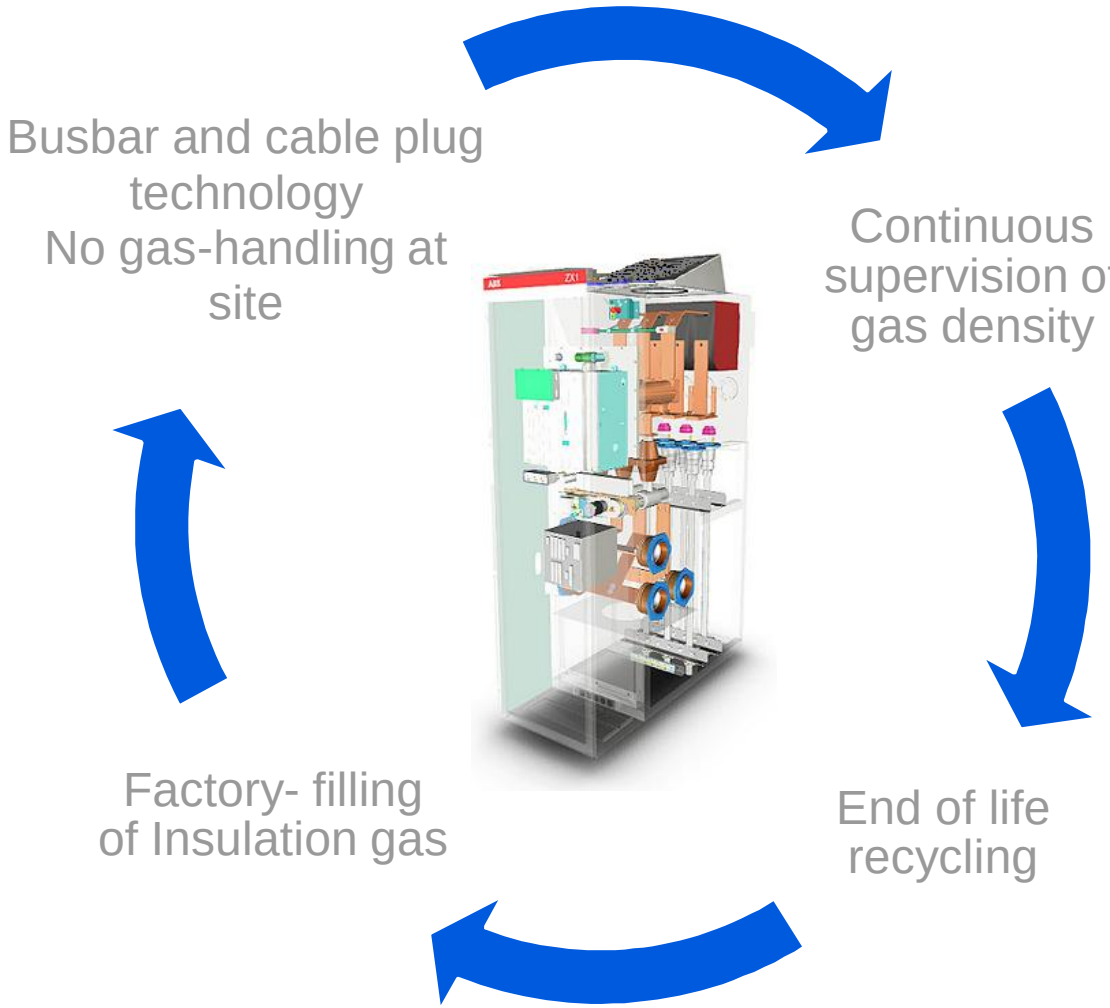
Non-toxic

Easy handling



High global warming potential
(GWP 22.800)

Switchgear history and trends
Sustainability in current ABB MV-GIS portfolio



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
- SF_6 reporting obligation and taxation in certain countries

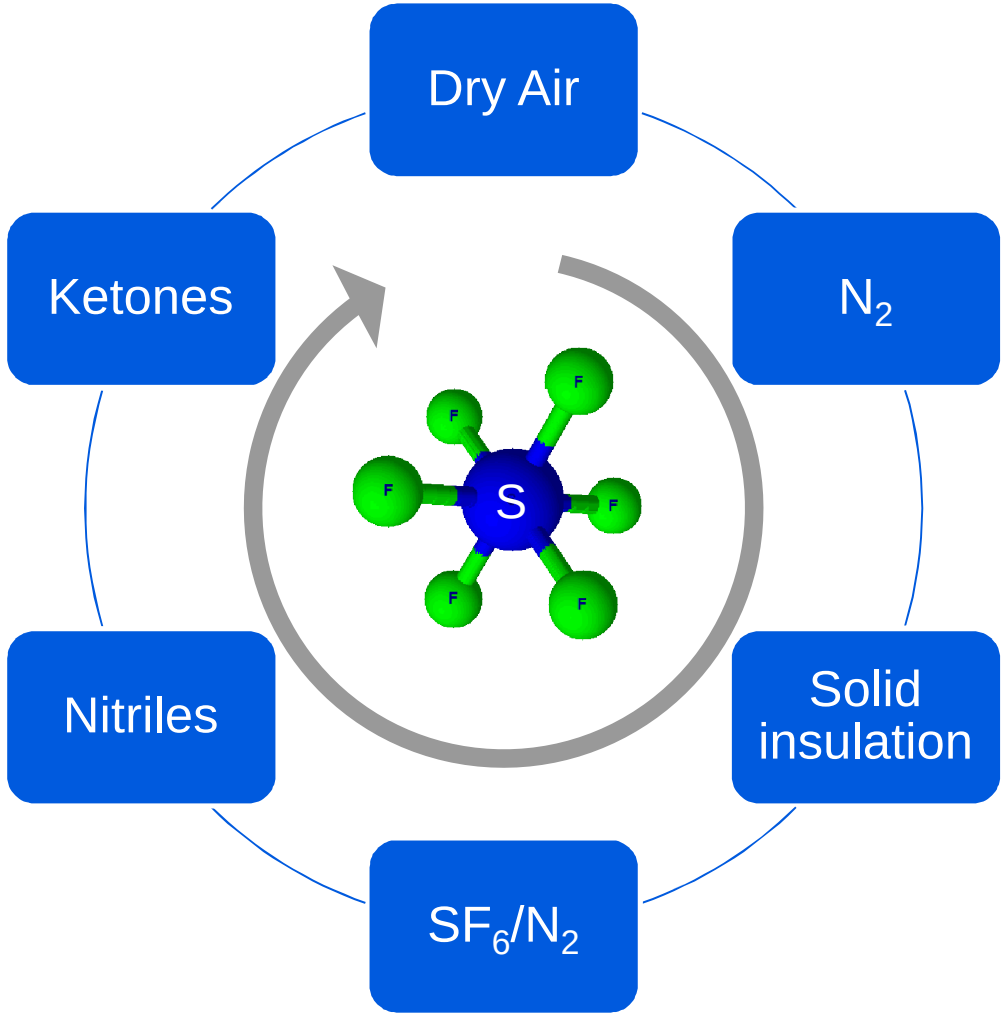
- 2010: New promising fluids are developed
  ABB starts research of application

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 SF_6

Extensive research on various options



Years of extensive research

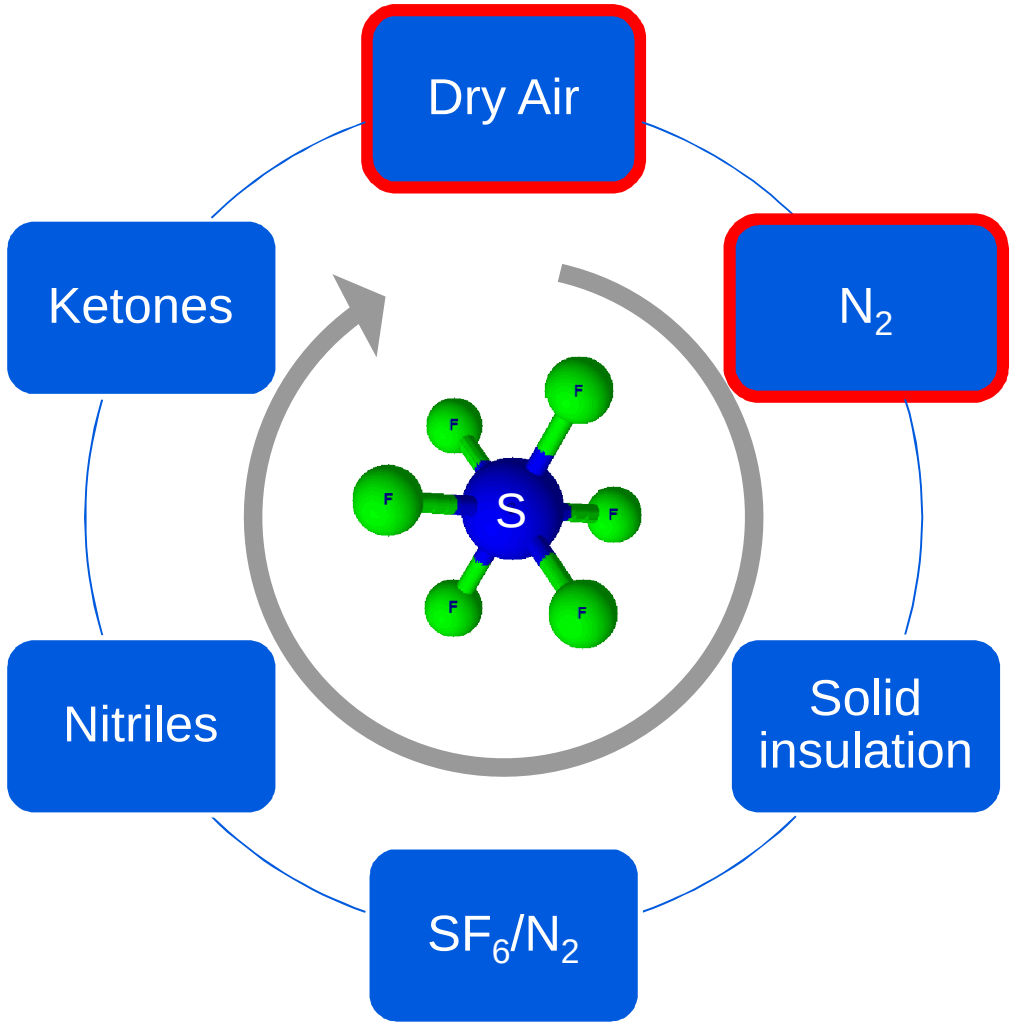
- ABB Corporate Research Centers
- External partners

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

Extensive research on various options



Years of extensive research

- ABB Corporate Research Centers
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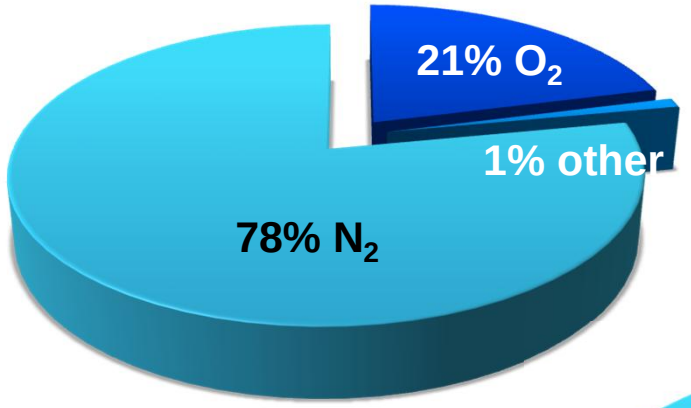
Evaluation criteria

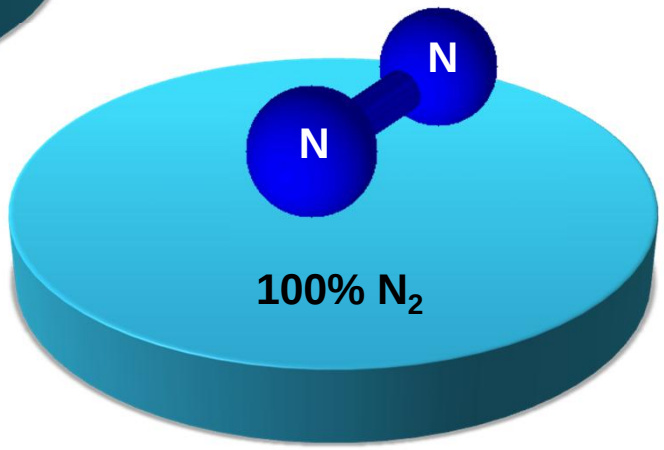
- Global warming potential (GWP)
- Dielectric properties & compactness
- Material compatibility
- Self-healing insulation
- Toxicity & flammability
- Recycling & sustainability

Research on eco-efficient alternatives to SF_6
Dry air and N_2

Evaluation	Dry air	N_2
Global warming potential (GWP)	++	++
Dielectric properties & compactness	o	-
Material compatibility	+	++
Self-healing insulation	+	+
Toxicity & flammability	++	++
Recycling & sustainability	++	++



Composition of air

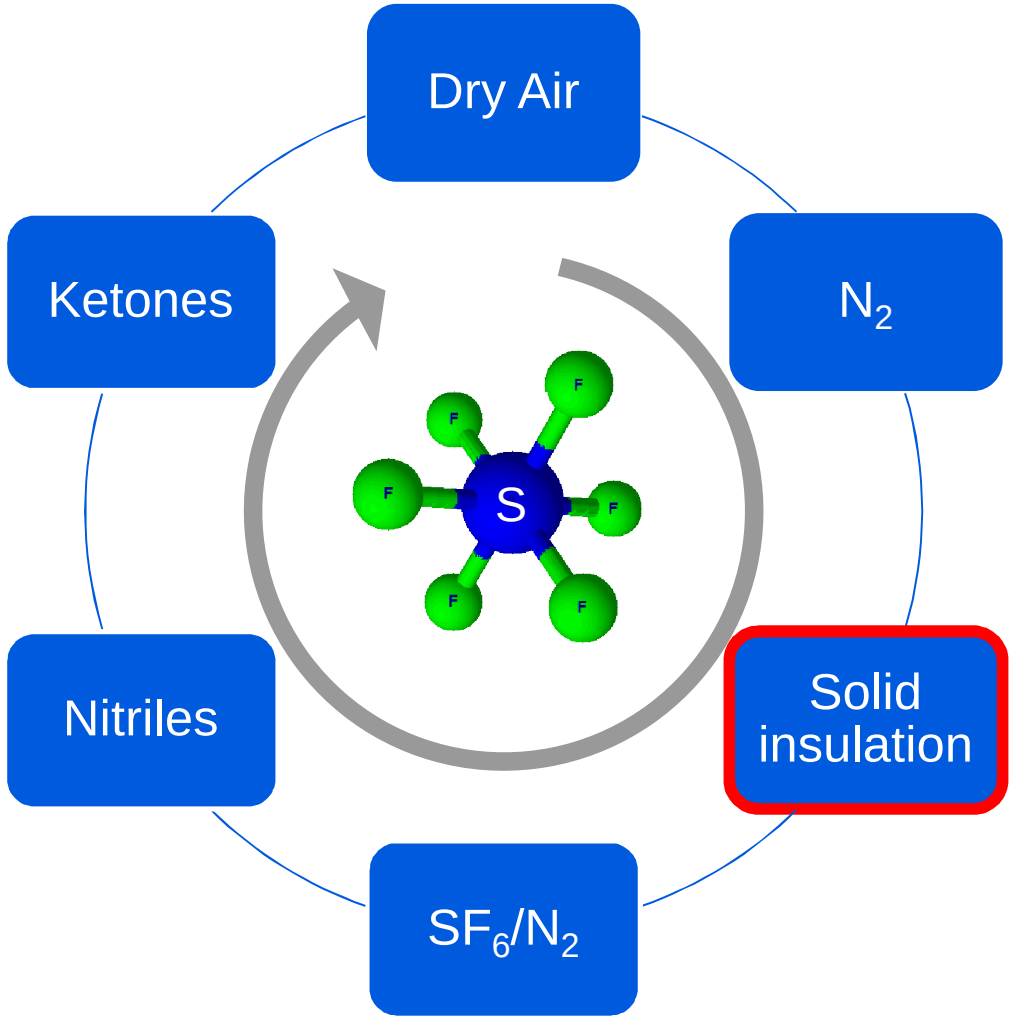


Pure nitrogen

- Dry air has slightly better dielectric performance than N2
- Pure N_2 does not contain O_2, so better material compatibility than air
- **Dielectric performance limited, but solution for lower voltages**

Research on eco-efficient alternatives to SF_6

Extensive research on various options



Years of extensive research

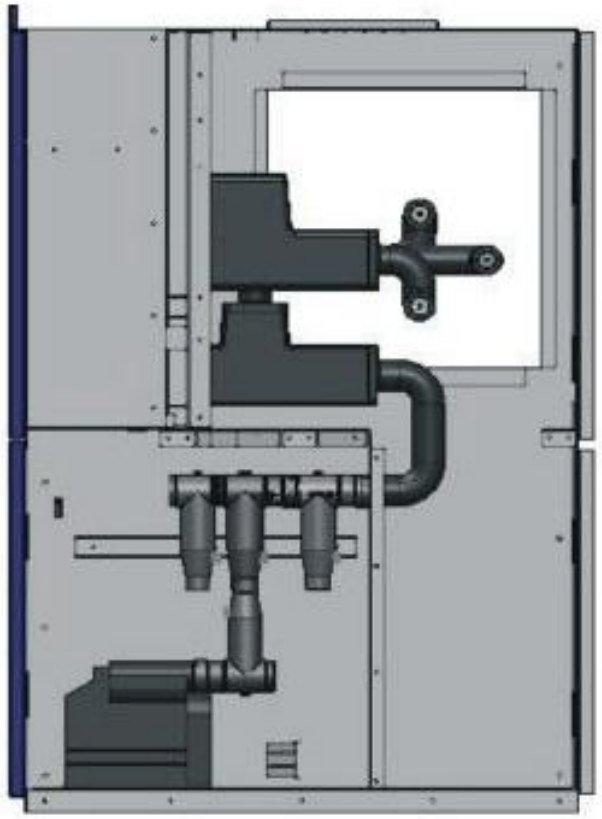
- ABB Corporate Research Centers
- External partners

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
Solid insulation

Evaluation	
Global warming potential (GWP)	++
Dielectric properties & compactness	+
Material compatibility	++
Self-healing insulation	--
Toxicity & flammability	-
Recycling & sustainability	-

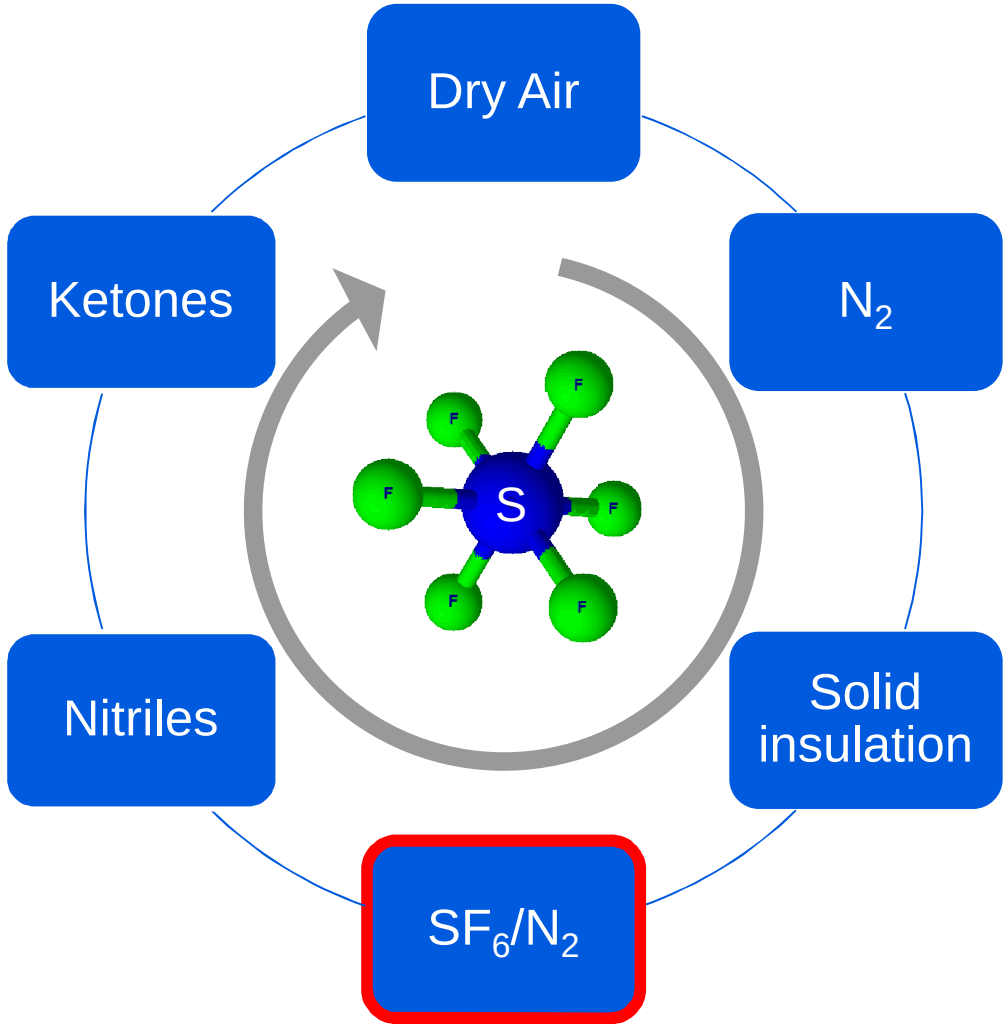


- Not self-healing, no repair possible (partial discharge)
- No recycling possbile, energy intensive production

→ **No reliable and sustainable solution for ABB**

Research on eco-efficient alternatives to SF_6

Extensive research on various options



Years of extensive research

- ABB Corporate Research Centers
- External partners

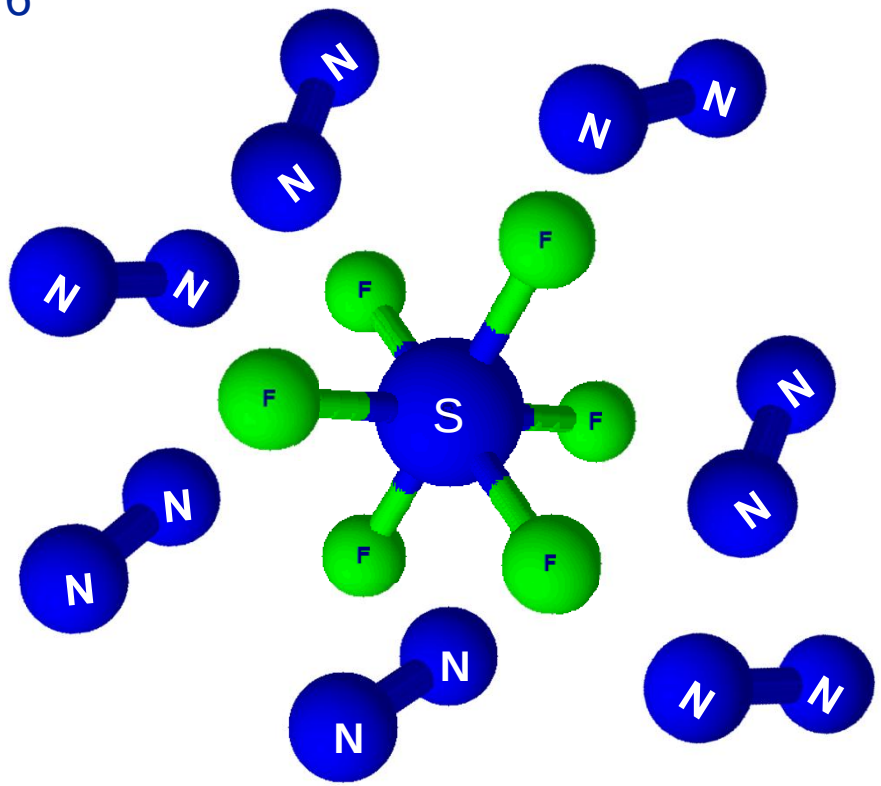
Evaluation criteria

- Global warming potential (GWP)
- Dielectric properties & compactness
- Material compatibility
- Self-healing insulation
- Toxicity & flammability
- Recycling & sustainability

Research on eco-efficient alternatives to SF_6

SF_6 mixes with N_2

Evaluation	
Global warming potential (GWP)	-
Dielectric properties & compactness	+
Material compatibility	++
Self-healing insulation	+
Toxicity & flammability	++
Recycling & sustainability	-

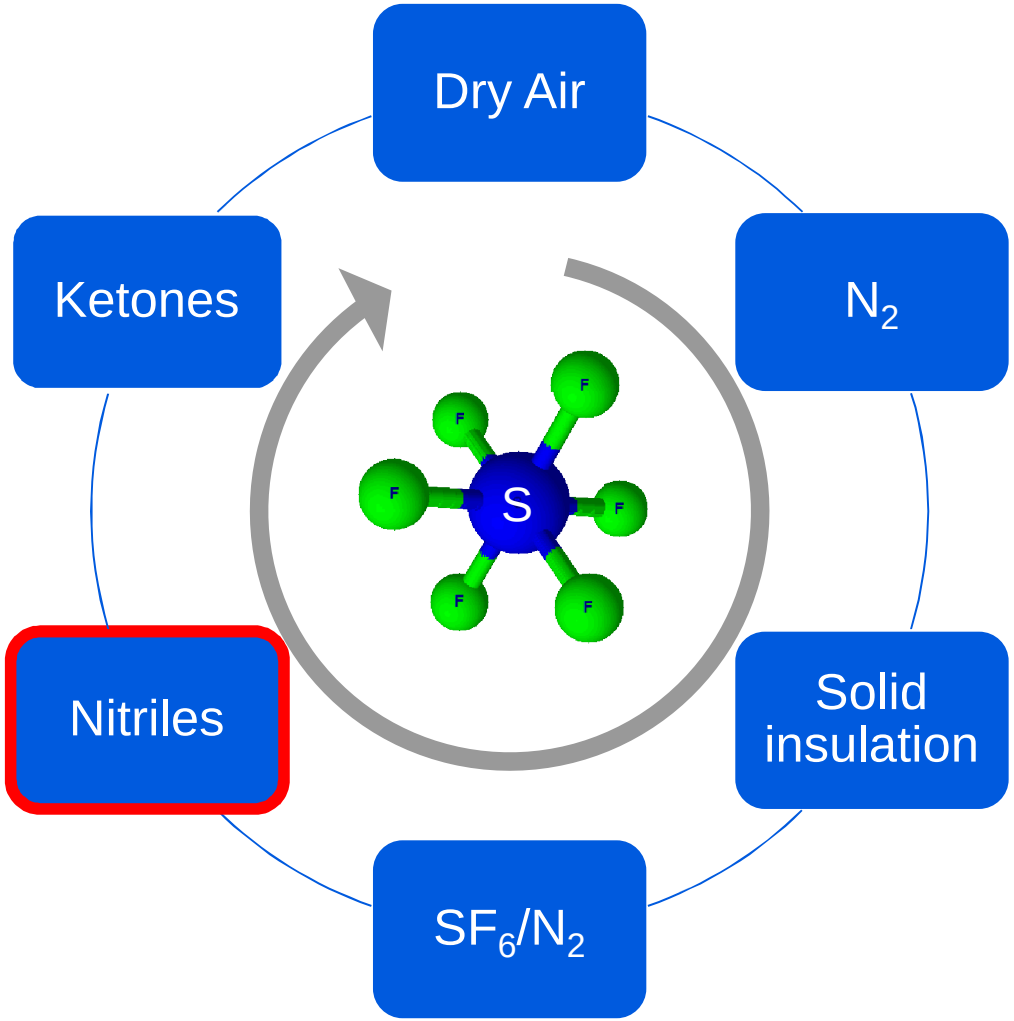


- Still rather high GWP
- Recycling of gas mixture difficult

→ **No eco-efficient solution**

Research on eco-efficient alternatives to SF_6

Extensive research on various options



Years of extensive research

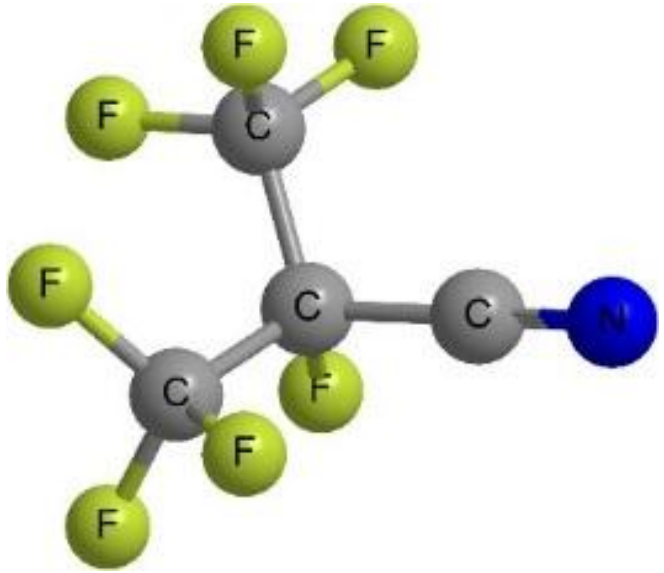
- ABB Corporate Research Centers
- External partners

Evaluation criteria

- Global warming potential (GWP)
- Dielectric properties & compactness
- Material compatibility
- Self-healing insulation
- Toxicity & flammability
- Recycling & sustainability

Research on eco-efficient alternatives to SF_6
Nitriles mix with air

Evaluation	
Global warming potential (GWP)	o/-
Dielectric properties & compactness	+
Material compatibility	+
Self-healing insulation	+
Toxicity & flammability	+
Recycling & sustainability	+

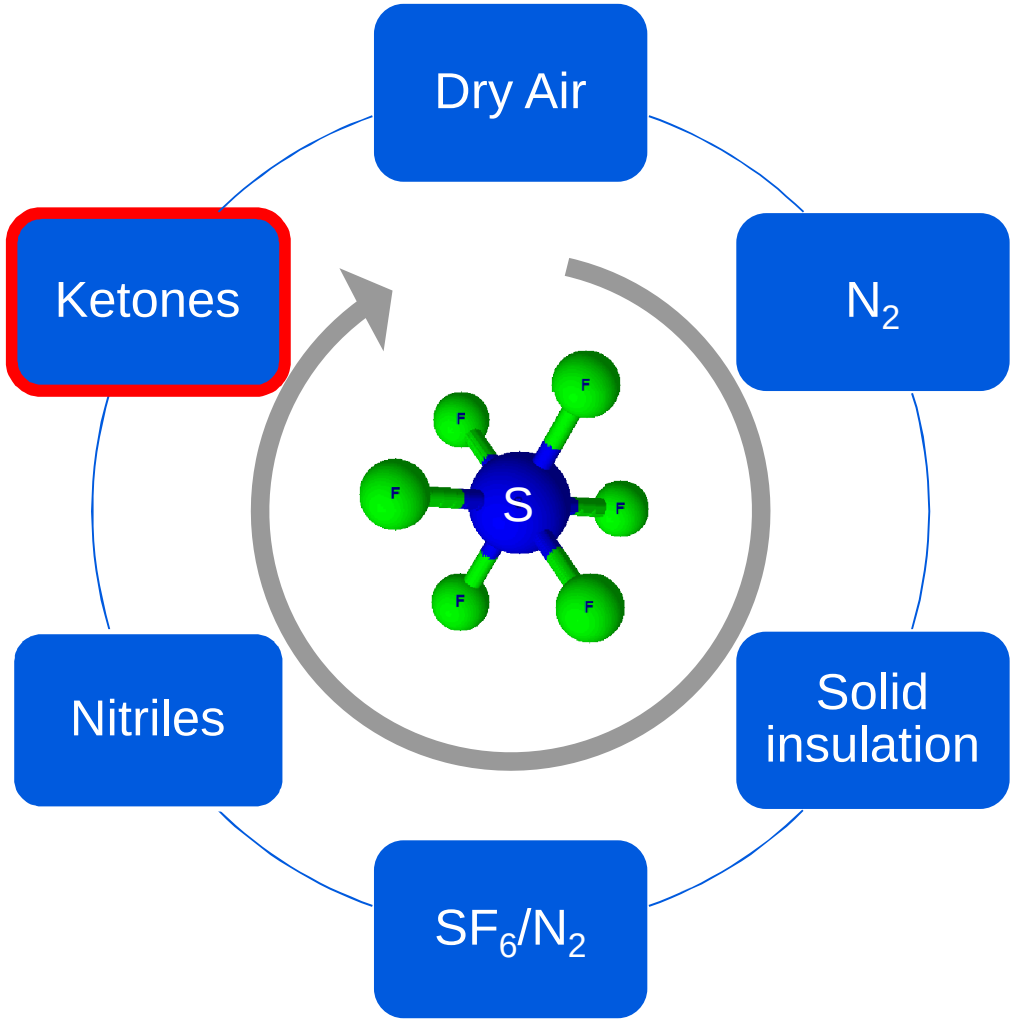


- Technical performance close to SF_6
- GWP still in range of 1.000

→ **No real eco-efficient solution**

Research on eco-efficient alternatives to SF_6

Extensive research on various options



Years of extensive research

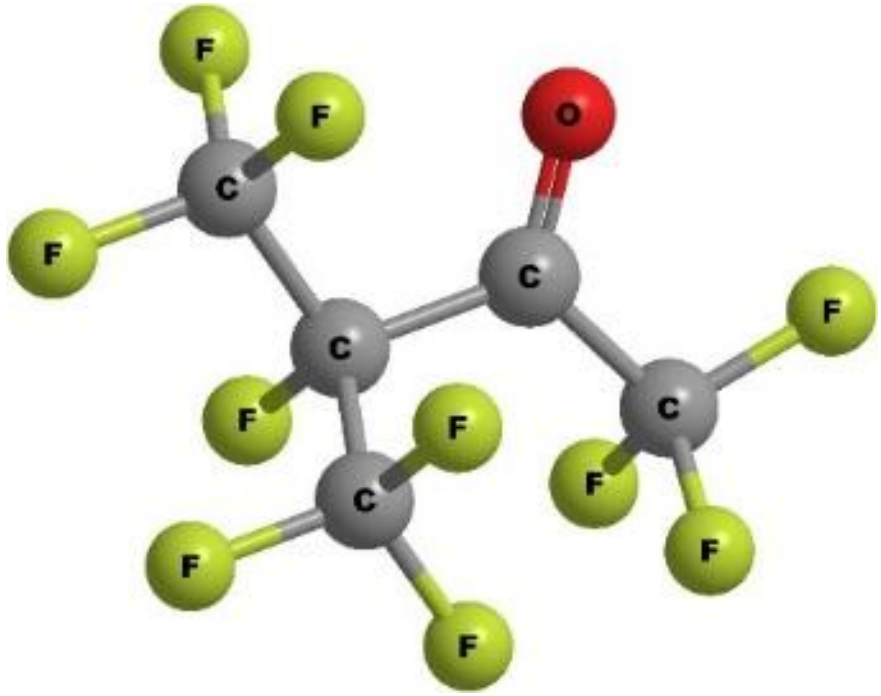
- ABB Corporate Research Centers
- External partners

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

Evaluation	
Global warming potential (GWP)	++
Dielectric properties & compactness	+
Material compatibility	+
Self-healing insulation	+
Toxicity & flammability	+
Recycling & sustainability	+



- Very low GWP < 1
- Technical performance close to SF_6

→ **Technically and environmental-friendly best alternative**

Research on eco-efficient alternatives to SF_6
GWP vs Performance

Identified "Low GWP" alternatives:

GWP = 0:

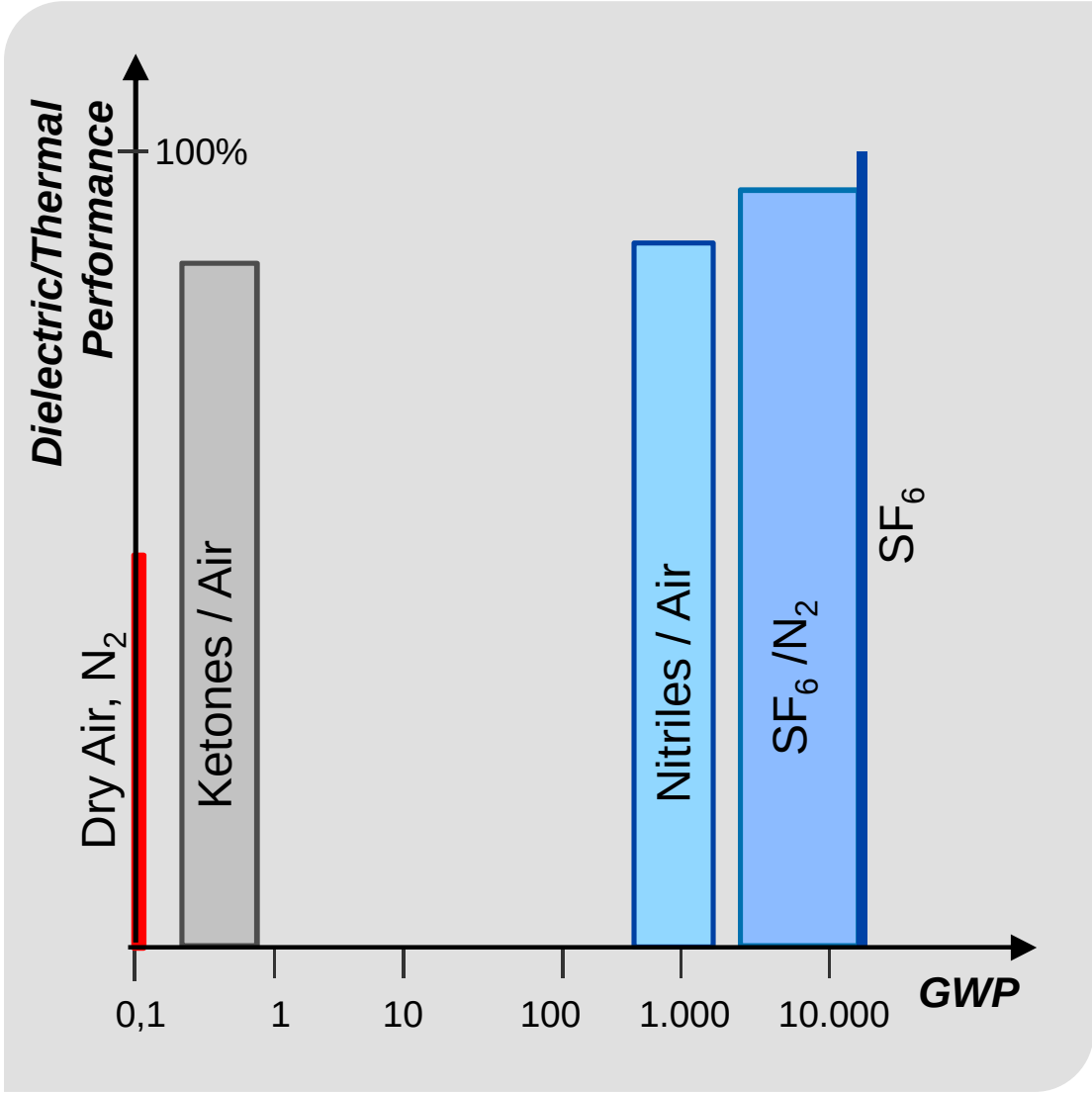
- Dry Air and N_2 are possible candidates
- Dry Air has better performance than N_2

GWP > 0:

- Ketones and Nitriles close to SF_6 performance
- Ketones much lower GWP than Nitriles

	GWP *
Ketones / Air mix	<1
Nitriles / Air mix	1.500 - 2.000

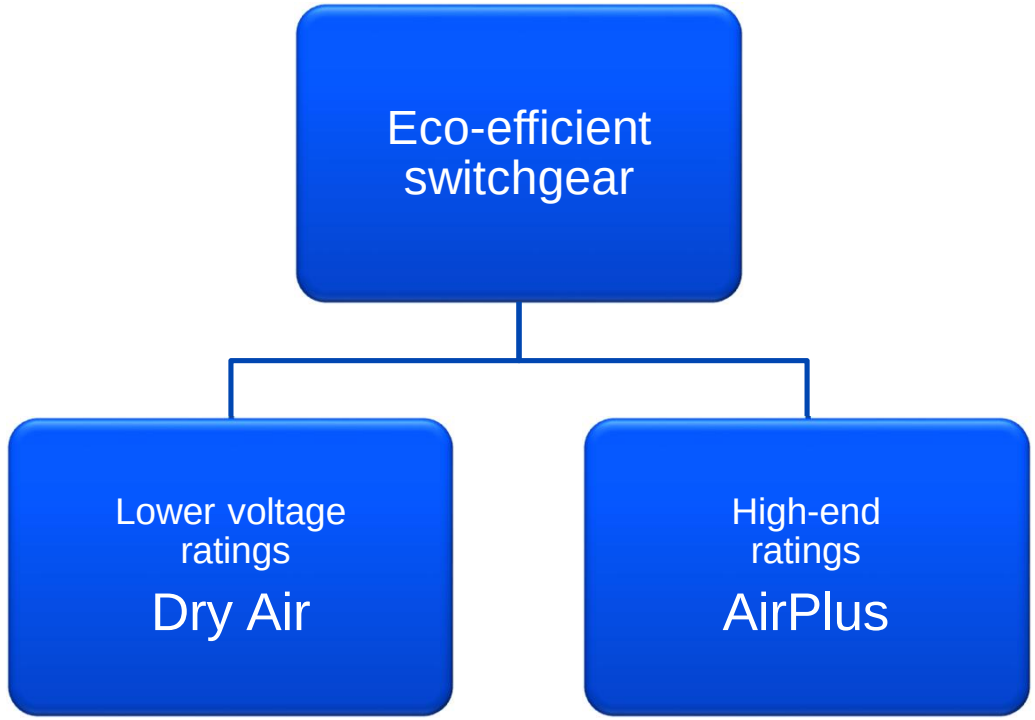
*** for MV GIS applications**



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

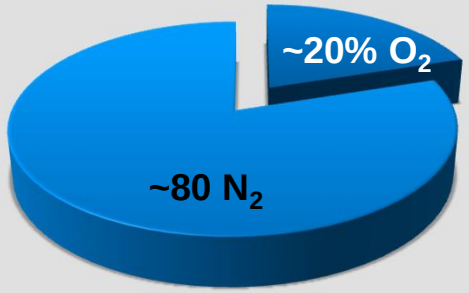


New **Ketones** gas mixture achieves close to
100% reduction of GWP;
Dry Air has no GWP

Research on eco-efficient alternatives to SF_6
Details on ABB's two eco-efficient insulation gases

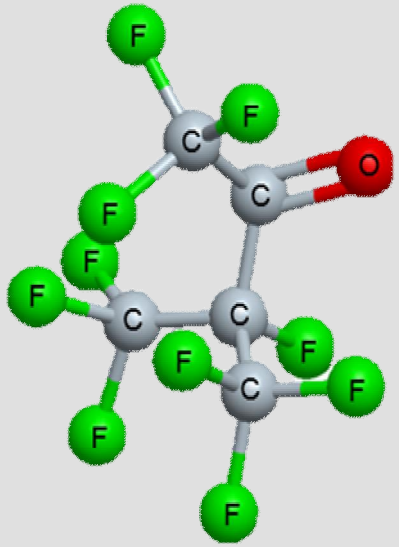
DryAir technology

- 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_2, O_2) with Perfluoro Ketones (C5 FK).
- Pure gas of C5 FK has much better dielectric strength than SF_6. Dielectric strength of mixture close to SF_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_2 can be added to the mixture

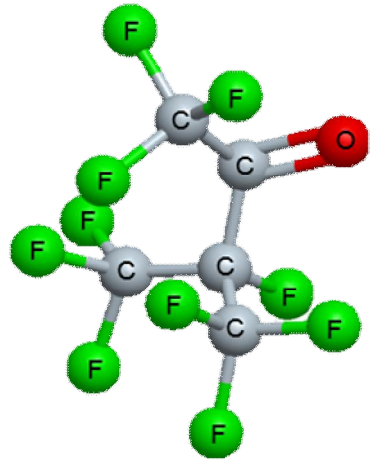


ABB's eco-efficient switchgear

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

New **Ketones** gas mixture achieves close to
100% reduction of GWP;
Dry Air has no GWP

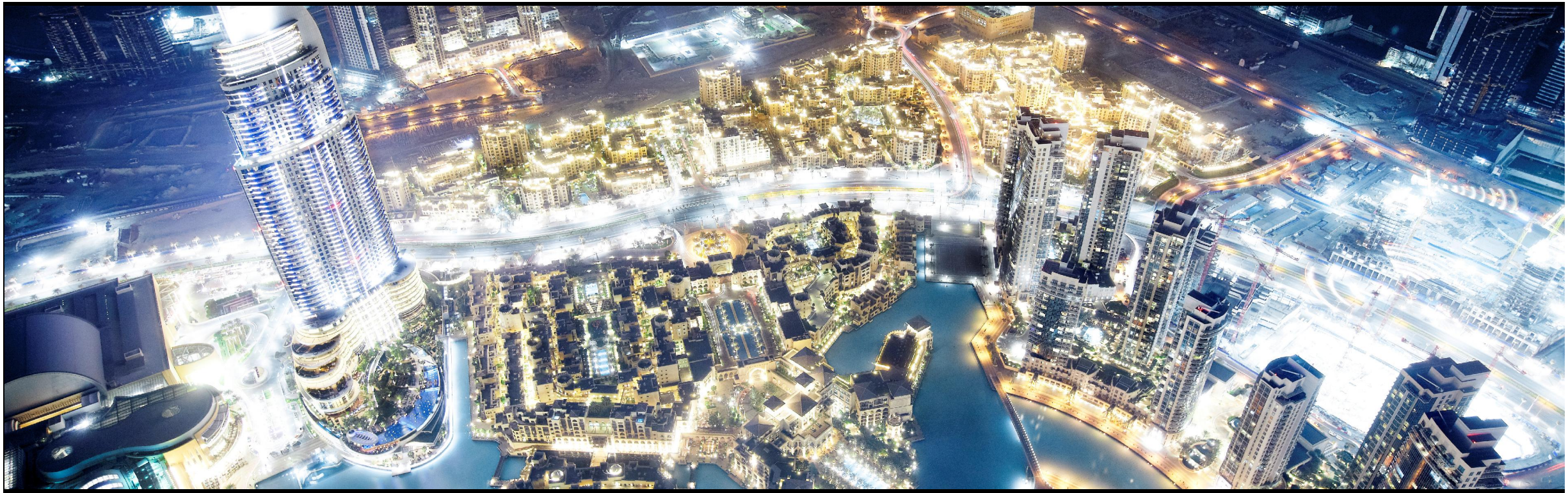


ABB Medium Voltage Days MEA 2016

Medium-voltage GIS portfolio
Part 2
Smart secondary distribution switchgear

Power and productivity
for a better world™

Society having higher demands on power distribution
Benefits of smart grids

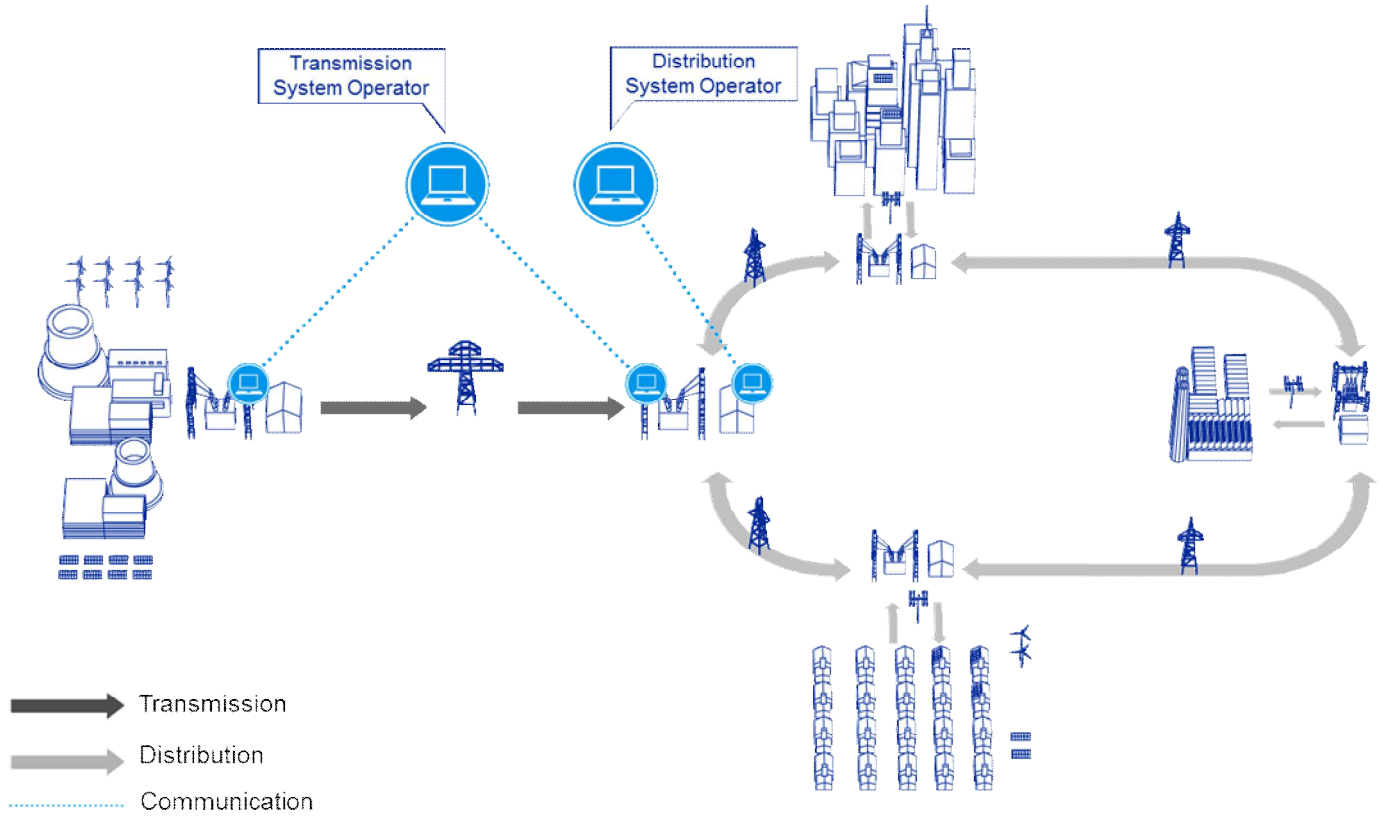
Reliability	Distributed Generation	Better Customer service
		

- 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

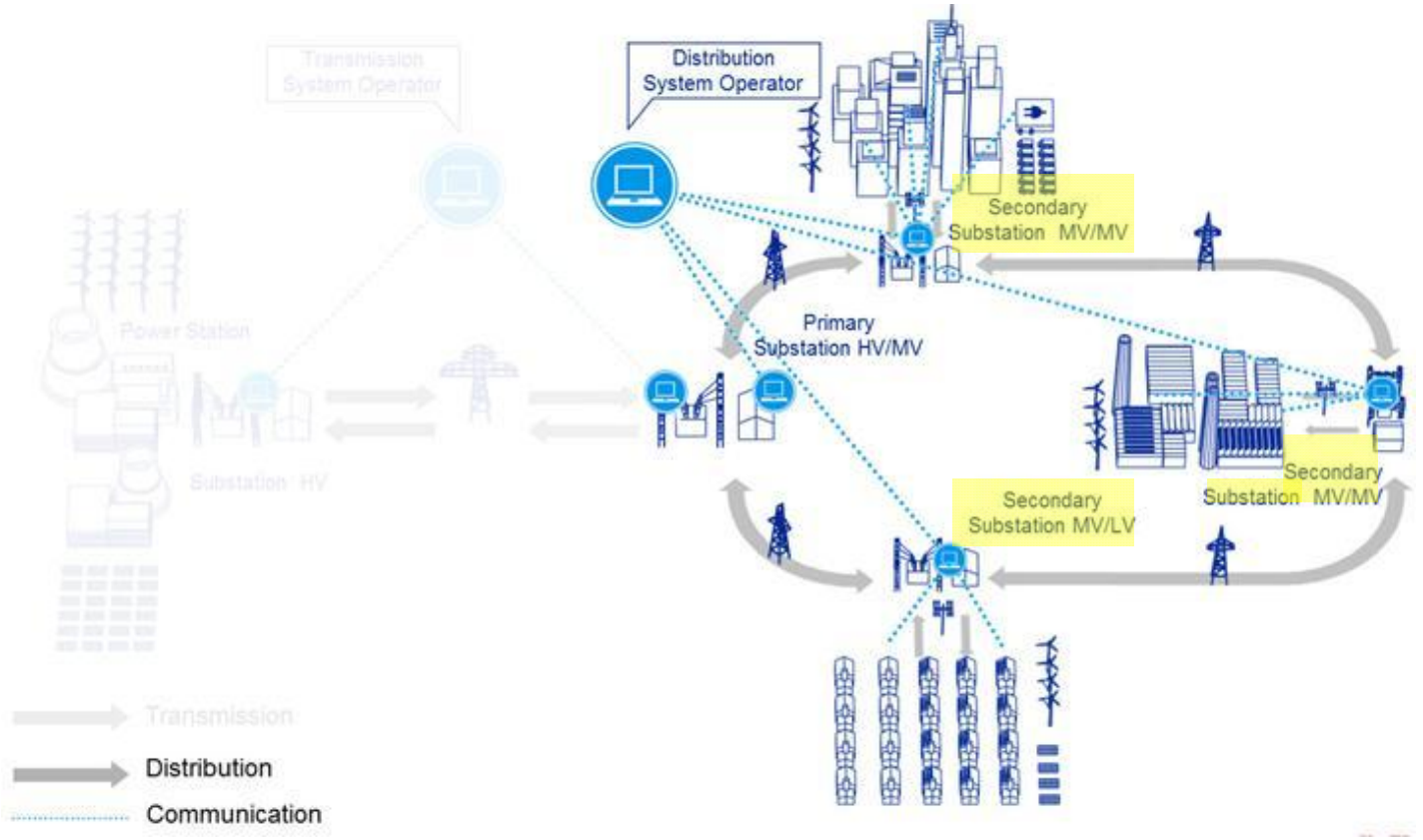
- **Distribution Control Centers**
  - Network management SCADA/DMS
  - Outage Management
  - Workforce management
- **Primary Substation Automation**
  - Integrated Protection,Control and Monitoring



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

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
				PROTECTION
			MEASUREMENT	MEASUREMENT
		CONTROL	CONTROL	CONTROL
	MONITORING	MONITORING	MONITORING	MONITORING
	Situation Awareness	Fault Isolation	Power Flow Measurement	Protection Selectivity
Functions	• Indication of Switch status • Fault passage Indication (FPI) • LV Measurements • Condition Monitoring	• Remote control of Switches • Remote network Configuration	• High accuracy measurement (V,I,P,Q,f)	• Directional O/C and E/F protect. • Protect. Interlocking by GOOSE
				
	Wireless Gateway	**Wireless Controller**	**IED**	**IED**
	ARR600	ARC600	REC615	REC615

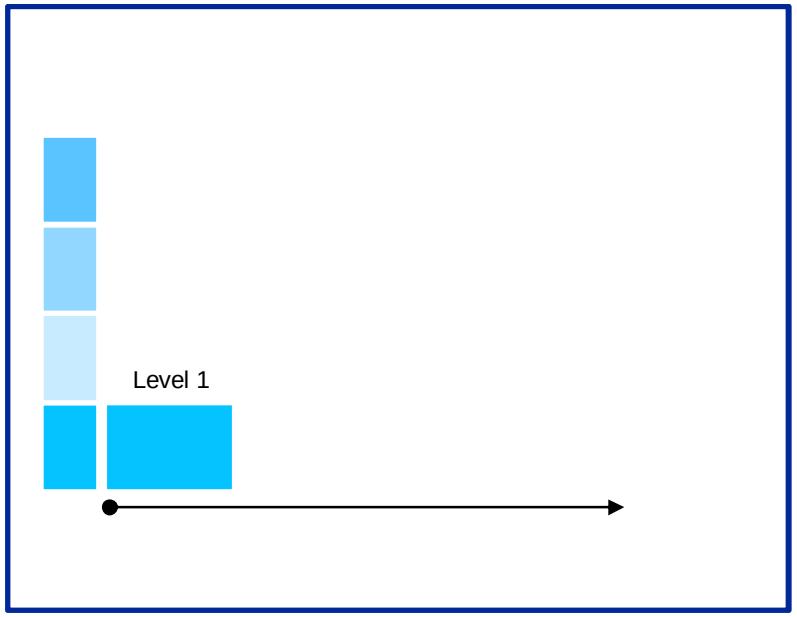
Solutions for smart secondary distribution
Situation awareness

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



Monitoring

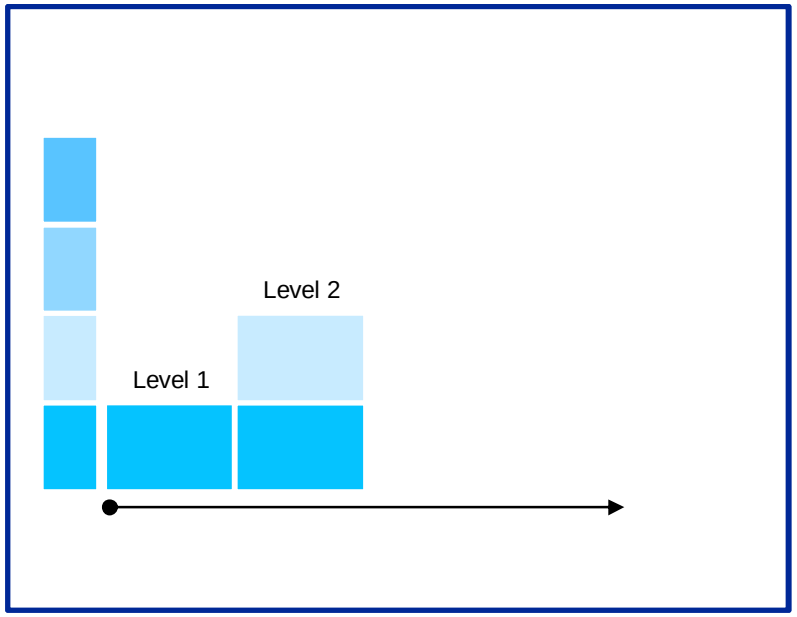
Solutions for smart secondary distribution
Fault isolation

Functions

- Remote Control of switches
- Remote network configuration

Benefits

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



Control

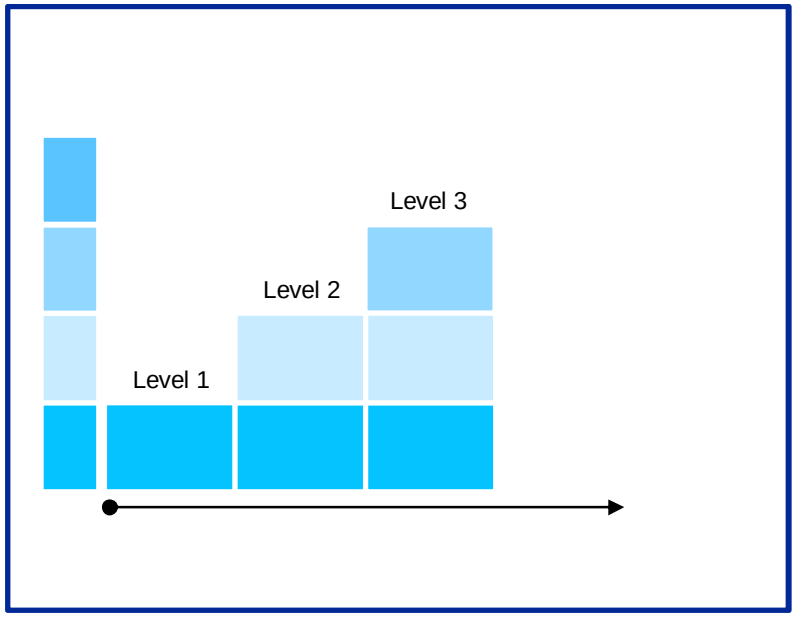
Solutions for smart secondary distribution
Power flow measurement

Functions

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

Benefits

- Voltage Stability even with intermittent distributed generation
- Increase network efficiency



Measurement

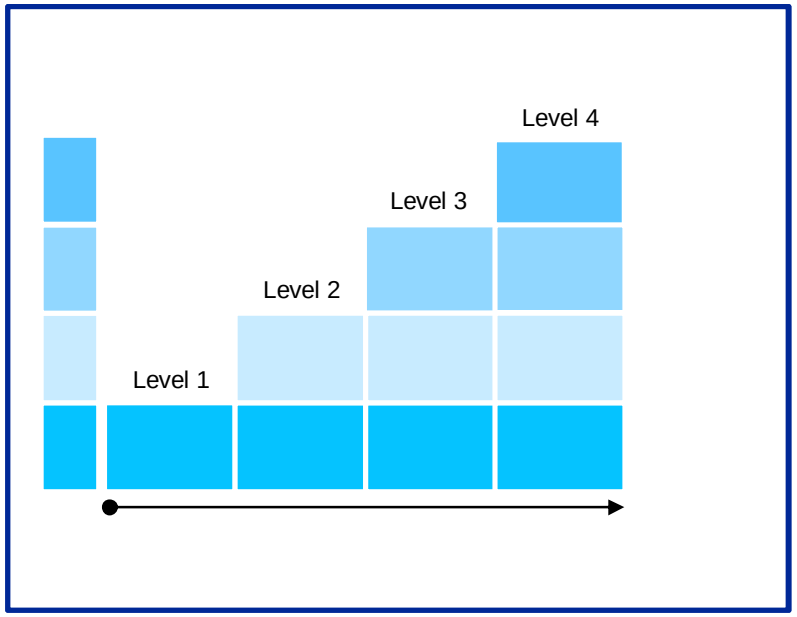
Solutions for smart secondary distribution
Protection selectivity

Functions

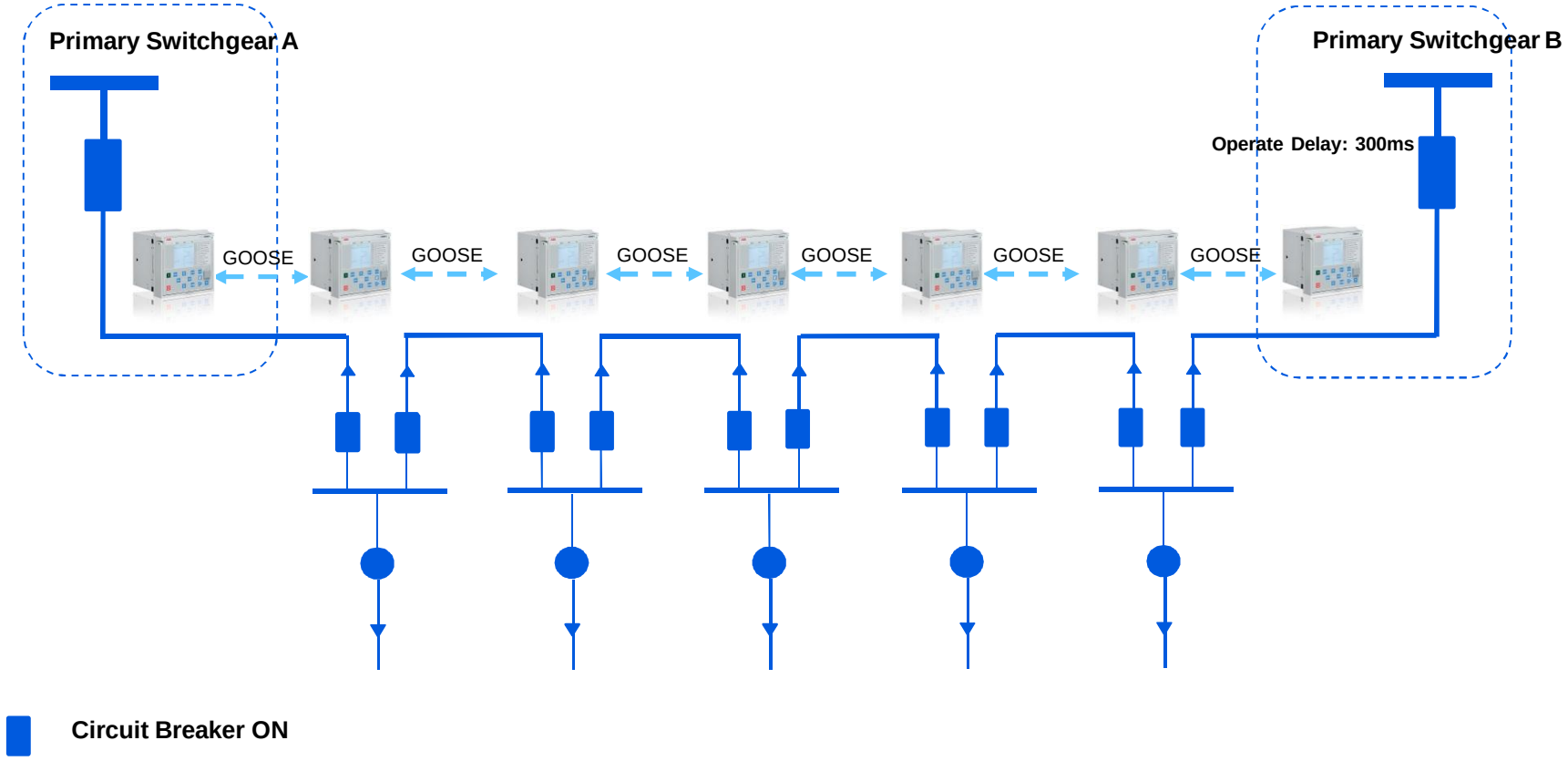
- Directional overcurrent and earth fault protection
- Reclosing for overhead lines
- Protection interlocking

Benefits

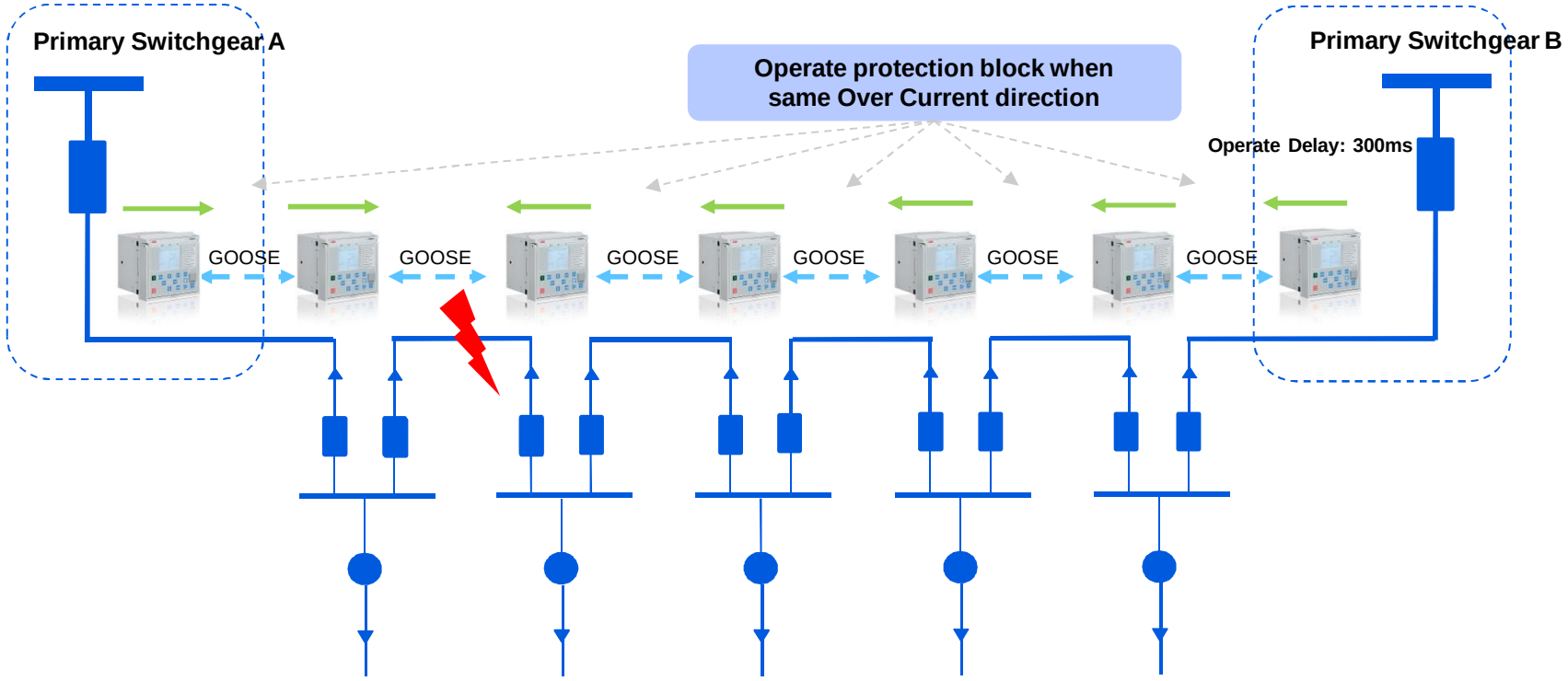
- Reduced number of outages



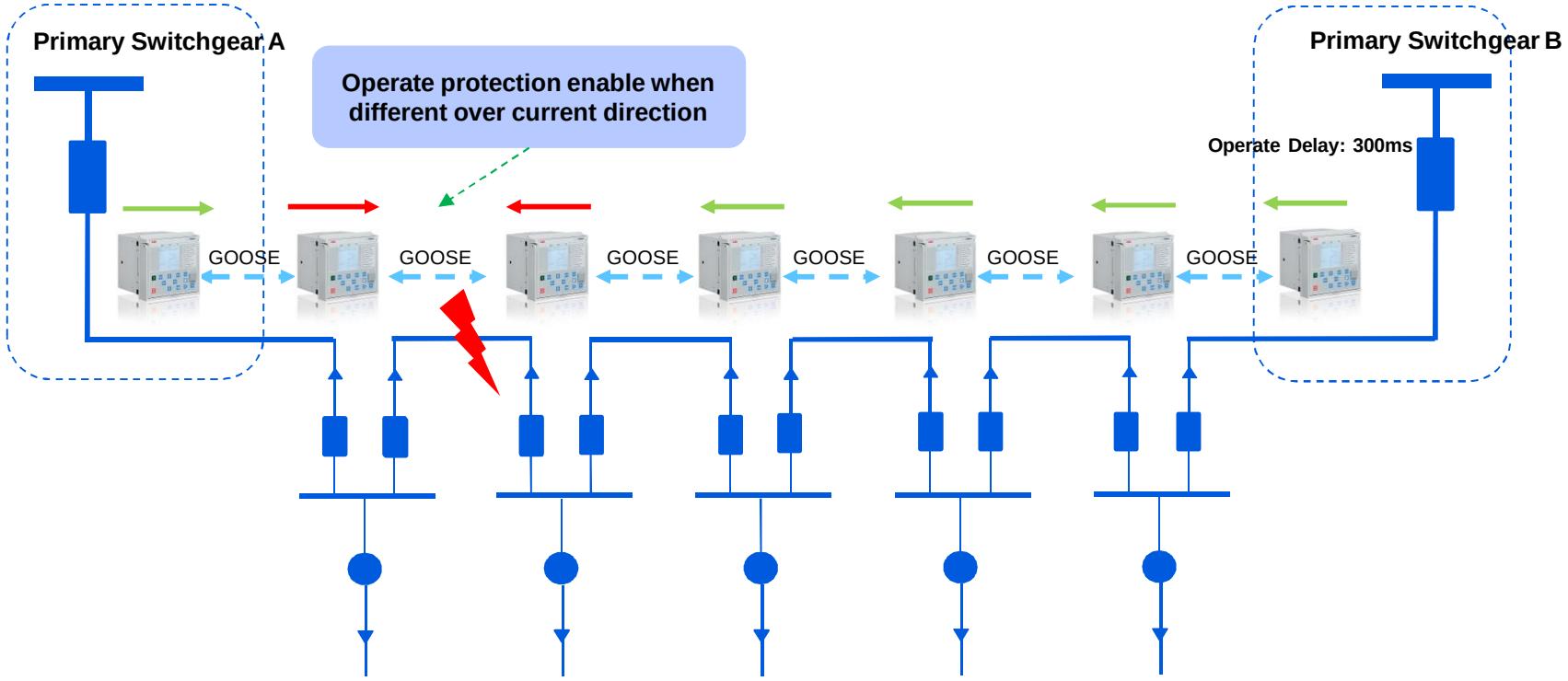
L4 Solution example
Logic selectivity in closed loop



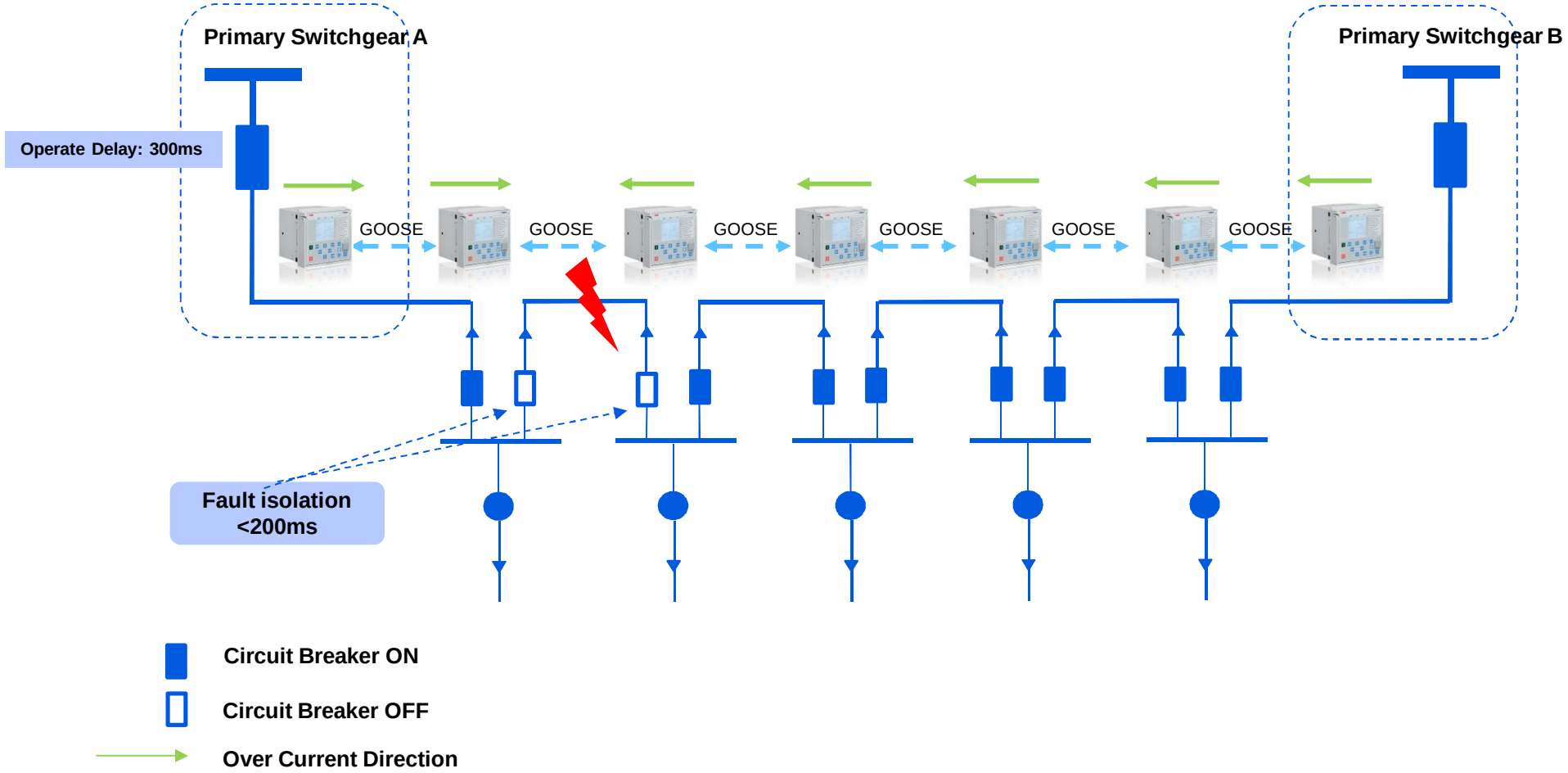
L4 Solution example
Logic selectivity in closed loop



L4 Solution example
Logic selectivity in closed loop

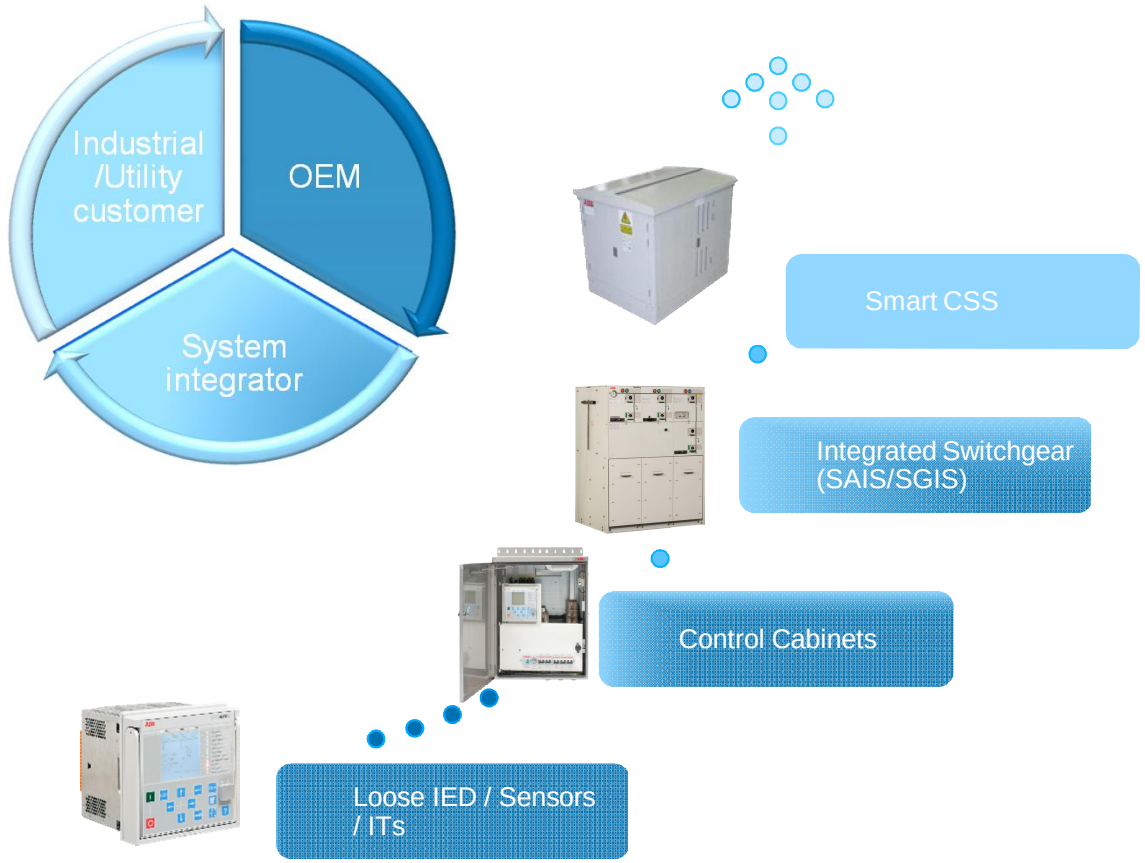


L4 Solution example
Logic selectivity in closed loop



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
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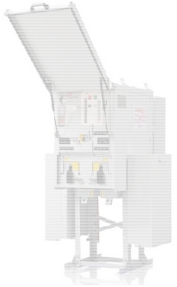

Safelink CB

Gas Insulated Outdoor Switchgear

Available up to 17,5kV

Safelink 2

Gas Insulated Outdoor Switchgear

Available up to 17,5kV

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

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Available up to 17,5kV

Safelink 2

Gas Insulated Outdoor Switchgear

Available up to 17,5kV

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

Enabling a stronger and smarter power network

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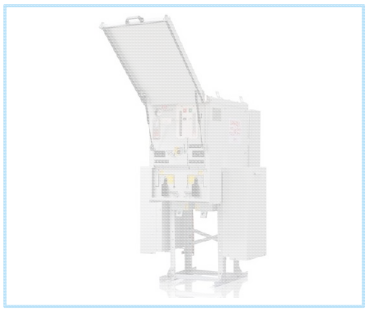


Safelink CB

Gas Insulated Outdoor Switchgear

Available up to 17,5kV

Safelink 2

Gas Insulated Outdoor Switchgear

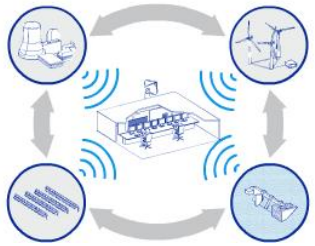
Available up to 17,5kV

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

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™