

CONNECTING AN ALL-ELECTRIC WORLD

Sustainable high-voltage products Blue Portfolio

Dr.-Ing. Dirk Helbig | Senior Principal High Voltage Products & Innovationmanager



Climate change

At the UN Climate Conference in Paris in 2015, almost all nations of the world agreed to limit anthropogenic global warming to well under 2° centigrade.

In the summer of 2017, earth's atmosphere had the highest concentration of carbon dioxide in 800,000 years.

Source: Earth System Research Laboratory, NOAA, October 5, 2017

Sustainability is a key enabler



We make real what matters by enhancing **responsible business practices**, preserving the **environment** and developing **people and society**.

Environment

- Decarbonization
- Resource conservation
- Product stewardship



Example: **Decarbonization**

- Environmental Portfolio helped our customers to reduce their CO₂-footprint by 521 million tons in FY16
- Siemens aims to become carbon neutral by 2030

Ownership and Operation

- Reliability
- Performance
- Economic efficiency



Reliable and cost-efficient

- Deliver proven reliability of Siemens HV Products
- Economics: Drive Decarbonization and life-cycle cost-efficiency: Investment, Operation, Maintenance, CO₂ compensation costs and Recycling

People and Society

- Health & Safety
- Diversity
- Education
- Corporate Citizenship
- Business to Society



Example: **Health & Safety**

- Our goal: Every employee should rely on an intact and safe working environment to return healthily and safely to their family and friends
- Programs: Healthy@Siemens and Zero Harm Culture

The high voltage product family – a comprehensive portfolio for long-term business sustainability

SIEMENS
Ingenuity for life

Gas-insulated switchgear



- GIS 8VM1 72,5 kV Vacuum Circuit Breakers+Clean Air
- GIS 8VN1 145 kV Vacuum Circuit Breakers+Clean Air
- GIS 8DN8 170 kV SF₆ & Vacuum Circuit Breakers+Clean Air (in dev.)
- GIS 8DN9 245 kV SF₆
- GIS 8DQ1 550 kV SF₆

SF₆

Zero CO₂e

Circuit breakers



- Live Tank SF₆ & Vacuum Circuit Breakers+Clean Air
- Dead Tank SF₆ & Vacuum Circuit Breakers+Clean Air (in dev.)
- Dead Tank Compact / Hybrid Modules SF₆
- Disconnecting Circuit Breaker SF₆
- Circuit Breakers for GIS SF₆

SF₆

Zero CO₂e

Disconnectors and earthing switches



- Centre Break
- Pantograph
- Semi-Pantograph
- Vertical Break
- Side Break
- Double Side Break
- Knee-Type
- V-Type
- Earthing Switches

Zero CO₂e

Surge arresters



- AIS Porcelain
- AIS Polymer
- GIS - SF₆ & Clean Air
- HVDC
- FACTS
- Distribution
- Railways
- Line Arresters

SF₆

Zero CO₂e

Instrument transformers



- Current Transf. AIS (Oil, SF₆ & Clean Air)
- GIS (Ind. & Sensors)
- Voltage Transf. AIS (Inductive: Oil, SF₆ & Clean Air; Cap) GIS (Ind. & RC-D.)
- Combined Transf. AIS (Oil, SF₆ & Clean Air)
- HVDC (RC-Div.)
- Capacitor Products

SF₆

Zero CO₂e

Coil products



- Air Core Dry Type Reactors
- Line Traps
- Arc Suppression Coils
- Super-conducting Fault Current Limiters

Zero CO₂e

Bushings



- Transformer Bushings AC & DC OIP, RIP, RIS
- Wall Bushings AC & DC RIP
- GIS Bushings (SF₆ & Clean Air)
- Generator Bushings RIP

SF₆

Zero CO₂e

Long rod insulators

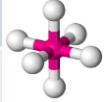
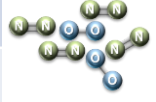
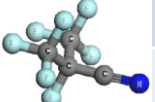
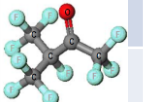


- Transmission line polymer insulators for systems up to 550 kV

Zero CO₂e

Properties of SF₆ and alternative gases

Clean Air most sustainable & stable with lowest operational costs

	SF ₆	Clean Air	Fluornitrile	C5-Fluorketone
Chemical formular	SF ₆ 	N ₂ + O ₂ (79,5%/20,5%) 	(CF ₃) ₂ CFCN 	(CF ₃) ₂ CFC(O)CF ₃ 
CO ₂ -equivalent	22.800	0	2.100 [2]	1 [3]
Boiling point (°Celsius)	-64°	< -183°	-4,7° [2]	+26,9° [3]
Gas mixture				
Carrier gas	Pur or mixed with N ₂ , CF ₄	-	96% for GIL [4] 94% CO ₂ for GIS [5]	83% CO ₂ / 11% O ₂ [6]
CO ₂ -equivalent	≤ 22.800	0	327...462 [4]	< 1 [3]
Boiling point (°Celsius)	<- 64° (variable)	< -183°	-30°...-25°C [4, 5]	~ 0° [6]
Dielectric strength (at same pressure)	1 (normiert)	~ 0,43	0,7...0,75 for GIL [5] > 0,75 for GIS [5]	~ 0,7 [8] mixed with air
Arcing impact				
Dissociation/decomposition	~ 2000 K (reversib.) [1]	~ 7000 K (N2 reversib.) [1]	> 920 K (irreversib.) [4]	~ 970 K (irreversib.) [7]
Decomposition products	HF, SO ₂ , sulphur compounds	None under normal operating conditions (VIU) If failure: ozone, NOx	F-Nitrile [4]: HF, CO, COF ₂ , CF ₃ CN, C ₂ F ₅ CN, C ₂ F ₆ C5-K. [6]: HF, CF ₄ , C ₂ F ₆ , C ₅ F ₁₀ O, C ₃ F ₈ , C ₄ F ₁₀ , C ₃ HF ₇ C ₄ F ₈ , C ₄ F ₆ , C ₃ F ₆ , C ₂ F ₃ N, C ₂ N ₂ in MV GIS with air [7]	

Vacuum interrupter technology

Operational and environmental value

For more than 40 years successful operational experience in medium-voltage,
since 2010 in high-voltage

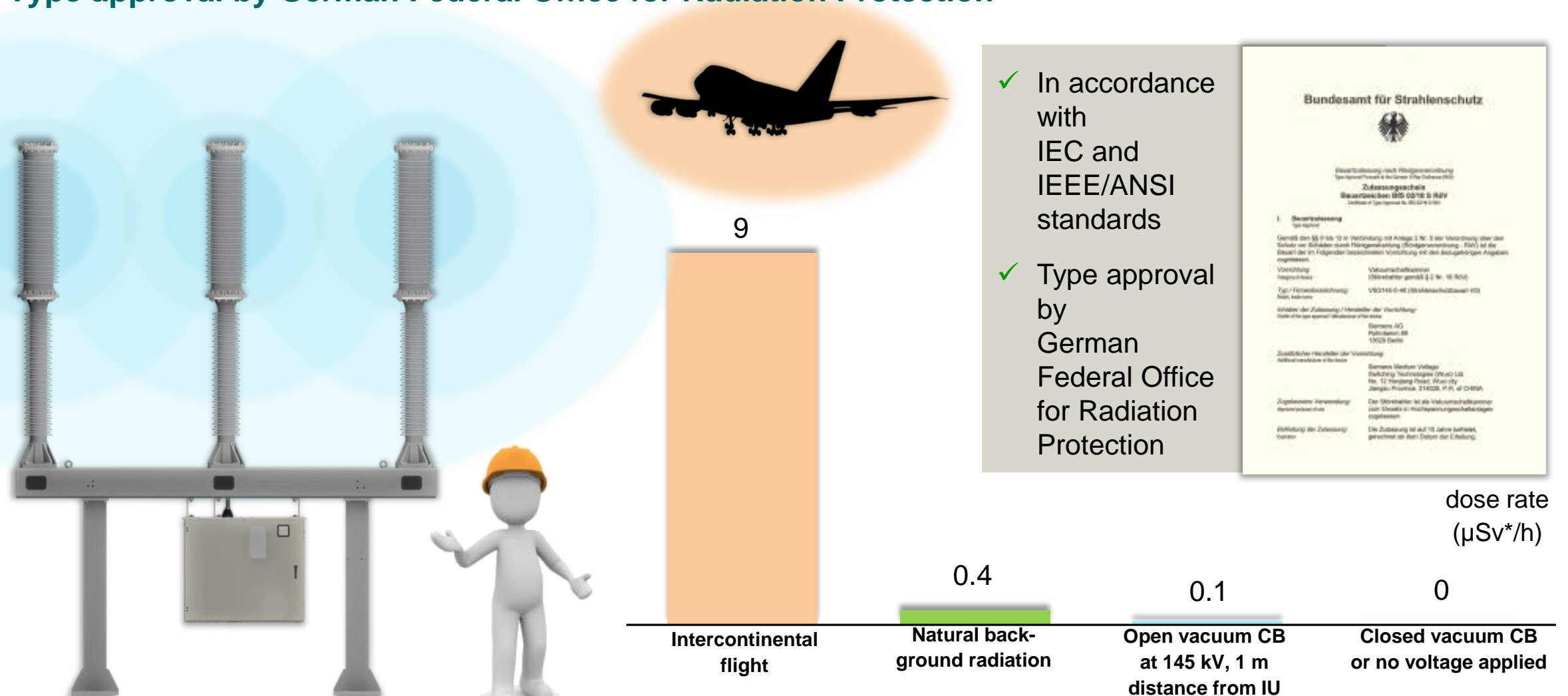
- **High reliability**
due to the hermetically tight vacuum interrupter,
eliminating any influence of decomposition products
- **High performance**
Perfect for frequent switching applications: Excellent interrupting performance at rated nominal current and rated short-circuit currents throughout life-time of the vacuum circuit-breaker, up to 30 short-circuit interruptions
- **Perfect for low temperature**
No liquefaction of switching medium
- **No maintenance**
Maintenance free due to sealed for life technology; no spare part costs
- **No CO₂e emissions**
Switching media (vacuum) with GWP=0;
no CO₂e emissions during operation, maintenance or recycling



Is x-ray radiation emitted by vacuum interrupters at high voltage an issue?

No, all values are well below limits of IEEE/ANSI and IEC standards.

Type approval by German Federal Office for Radiation Protection



- ✓ In accordance with IEC and IEEE/ANSI standards
- ✓ Type approval by German Federal Office for Radiation Protection



Source: [2018-3] S. Giere, T. Heinz, A. Lawall, C. Stiehler, E.D. Taylor, N. Wenzel, S. Wethekam, "X-Radiation Emission of High-Voltage Vacuum Interrupters: Dose Rate Control under Testing and Operating Conditions", ISDEIV International Symposium on Discharges and Electrical Insulation in Vacuum, Greifswald, 2018

Unrestricted © Siemens 2019.

The Future of High Voltage Switchgear Technology

Siemens CO₂ Neutral Switchgear Portfolio

SIEMENS
Ingenuity for life



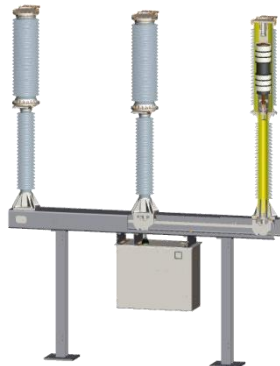
Air-insulated switchgear

Circuit Breaker

Instrument Transformer

Gas-insulated switchgear

145 kV



3AV1 blue

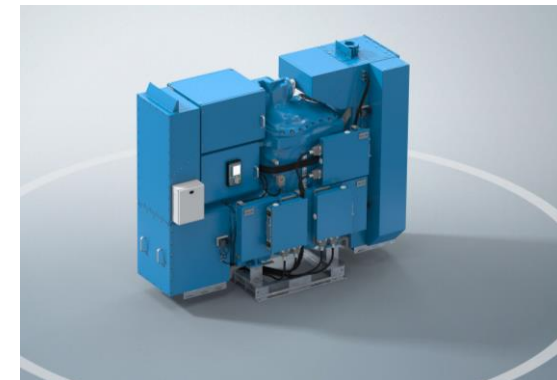
72,5 kV



SAS blue
SVS blue
SVAS blue
up to
420 kV



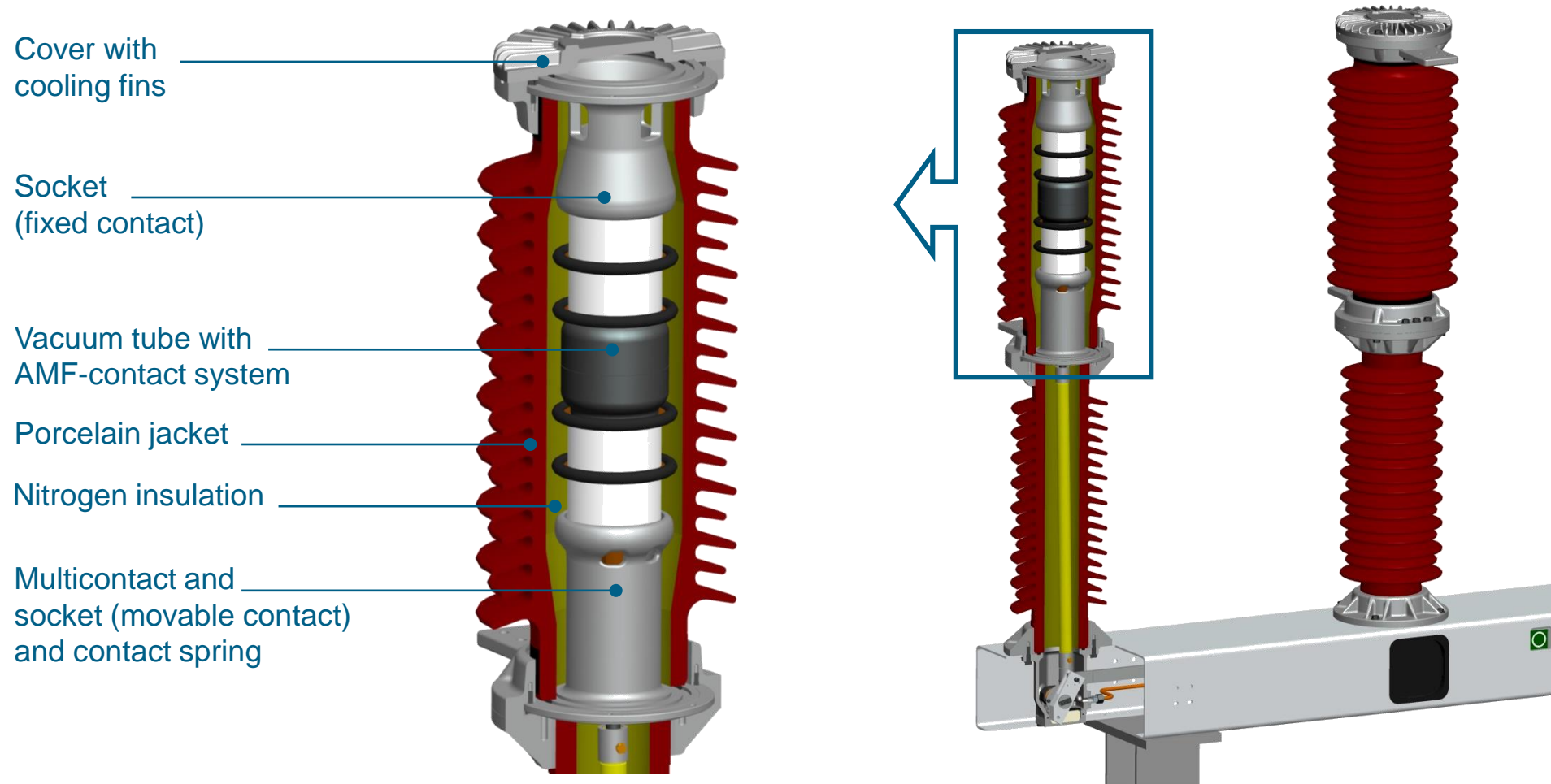
8VN1 blue



8VM1 blue

3AV1 72.5 kV Circuit-breaker design

SIEMENS
Ingenuity for life



3AV1 Live Tank 72.5 kV Type tested by PEHLA in 2010

SIEMENS
Ingenuity for life



The 3AV1 FG 72.5 kV has successfully been type tested according to latest IEC standard by the independent institute PEHLA. This also includes the necessary test concerning the potential emission of X-rays.

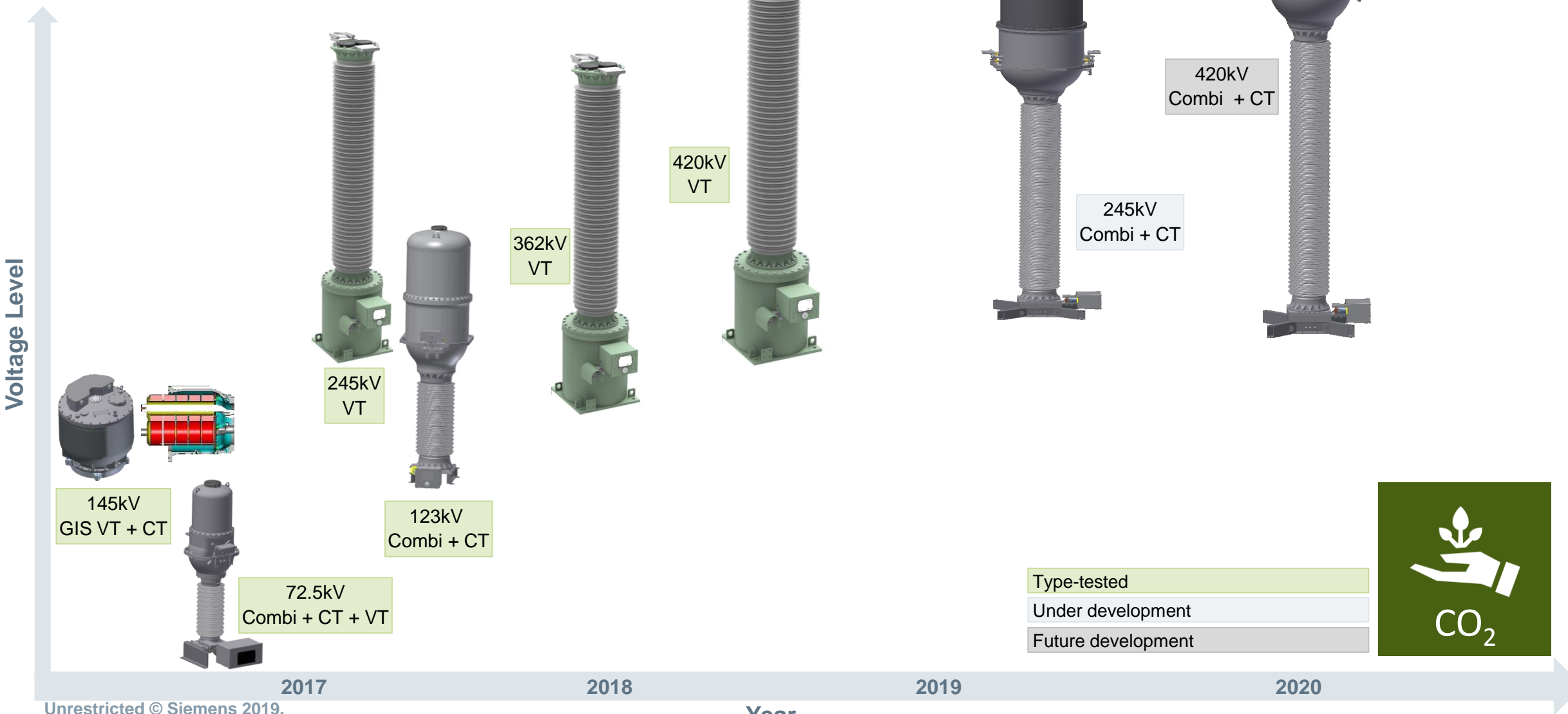
3AV1 Blue live tank circuit-breaker up to 145 kV

Technical data



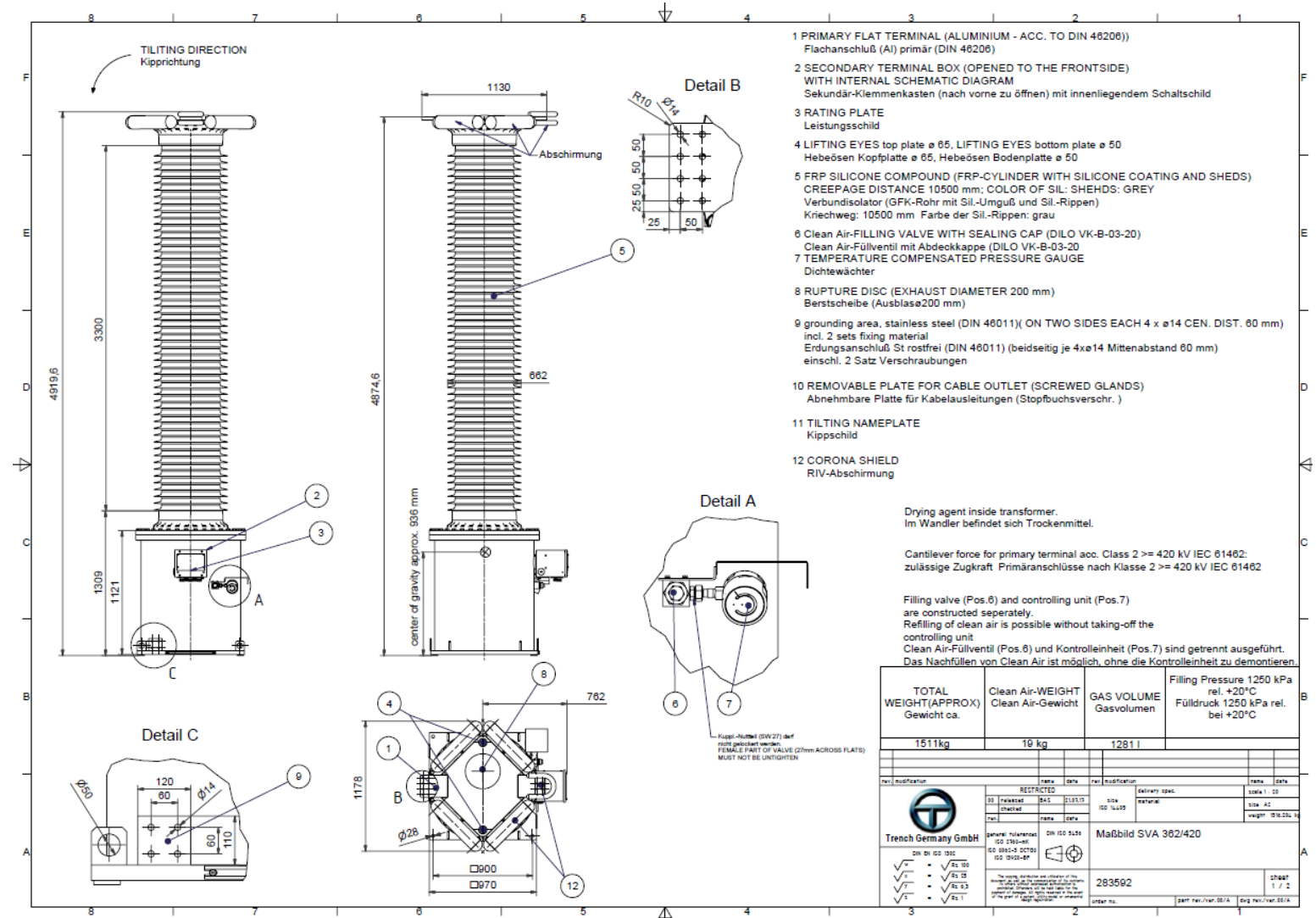
Switchgear type	3AV1 FG	
Rated voltage	up to	145 kV
Rated frequency		50 Hz
Rated short-duration power-frequency withstand voltage (1 min)	up to	275 kV
Rated lightning impulse withstand voltage (1.2 / 50 µs)	up to	650 kV
Rated continuous current	up to	3150 A
Rated short-circuit breaking current	up to	40 kA
Rated peak withstand current	up to	108 kA
Rated short-time withstand current (up to 3 s)	up to	40 kA
Leakage rate per year and gas compartment (type-tested)		< 0.1 %
Driving mechanism of circuit-breaker		stored-energy spring
Rated operating sequence		O-0.3 s-CO-3 min-CO CO-15 s-CO
Interrupter technology		Vacuum
Insulation medium		Clean Air
Weight of fluorinated greenhouse gases		0 kg
GWP global warming potential		0
CO ₂ equivalent		0 kg
Ambient temperature range	up to	-60 °C to +55 °C
First inspection		> 25 years
Expected lifetime		> 50 years
Standards		IEC
Other values on request		

Blue Instrument Transformer - Portfolio Roadmap



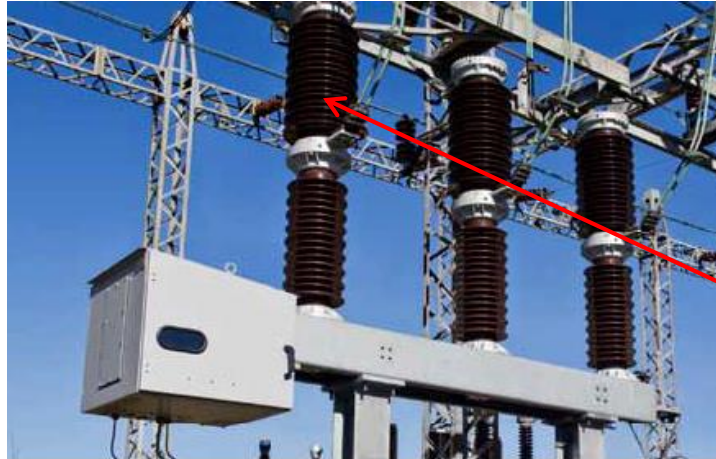
Unrestricted © Siemens 2019.

First Blue product available for 420 kV: Blue Voltage Transformer in Sensgear-Technology introduced at Hannovermesse 2019



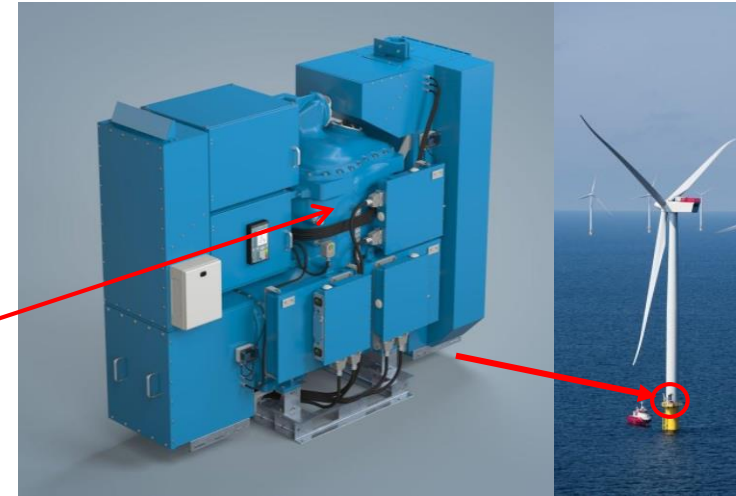
Vacuum-Interrupter are a joint base for air- and gas-insulated products and systems up to 420 kV

3AV1 vacuum circuit breaker, 72,5 kV, since 2010



3AV1FG 72.5 kV prototype

8VM1 GIS, 72,5 kV, first installation in 2017



- Worldwide leading **F-gas free** environmental friendly technology
- **Safe and easy** handling and work procedures
- **Sealed for life** vacuum interrupter and GIS bay: **no gas maintenance** for lifetime



Vacuum Technology with more than 40 years operational experience in medium-voltage

Circuit Breaker Innovation Roadmap

- 72,5 kV successful pilots since 2010
- 145 kV first installation 2017

GIS Innovation Roadmap

- 72,5kV first installation 2017
- 145 kV first installation 2019



Gas-Insulated Switchgear 8VM1 blue GIS up to 72.5 kV / 25 kA

Technical data

SIEMENS
Ingenuity for life

Switchgear type	8VM1	
Rated voltage	up to	72.5 kV
Rated frequency		50 / 60 Hz
Rated short-duration power-frequency withstand voltage (1 min)	up to	140 kV
Rated lightning impulse withstand voltage (1.2 / 50 µs)	up to	325 kV
Rated continuous current	up to	1250 A
Rated short-circuit breaking current	up to	25 kA
Rated peak withstand current	up to	68 kA
Rated short-time withstand current (up to 1 s)	up to	25 kA
Leakage rate per year and gas compartment (type-tested)		< 0.1 %
Driving mechanism of circuit-breaker		stored-energy spring
Rated operating sequence		O-0.3 s-CO-3 min-CO CO-15 s-CO
Interrupter technology		Vacuum
Insulation medium		Clean air
Weight of SF ₆ or other fluorinated greenhouse gases		0 kg
GWP Global Warming Potential		0
CO ₂ equivalent		0 kg
Rated filling pressure		0,56 MPa abs
Bay width common pole drive		1050 mm
Bay height, depth (depending on bay arrangement)		2330 mm x 2500 mm
Bay weight (depending on bay arrangement)		1,6 t
Ambient temperature range		-30 °C up to +45 °C
Installation		indoor
First major inspection		> 25 years
Expected lifetime		> 50 years
Standards		IEC / IEEE
Other values on request		

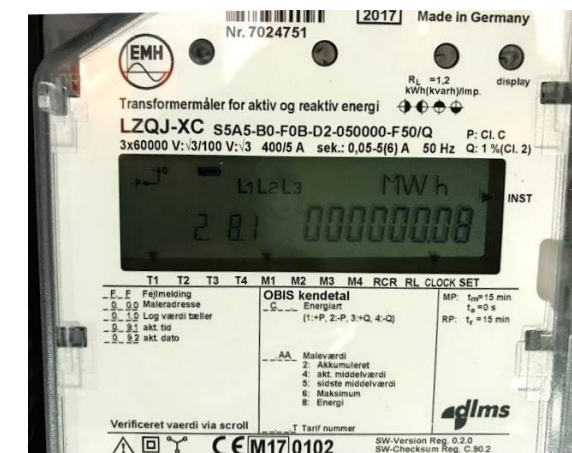
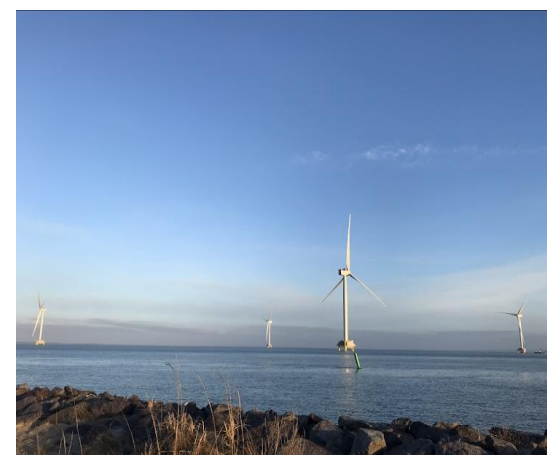
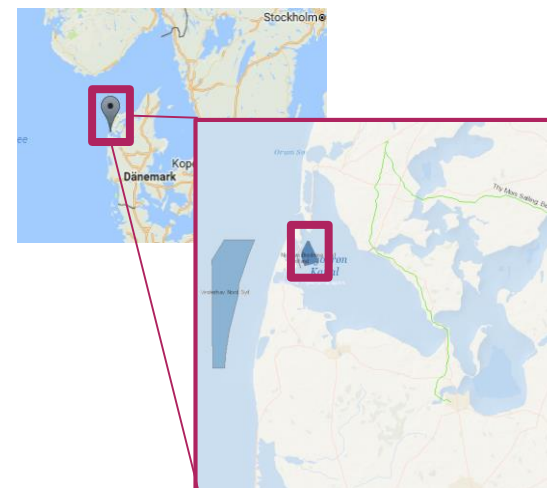


8VM1 - First installations 2017, energized 2018

SIEMENS
Ingenuity for life

Our first delivered 8VM1 blue GIS in offshore wind turbine generators were successfully energized!

The “Nissum Bredning” wind farm is online since 17.02.2018 and generating energy.

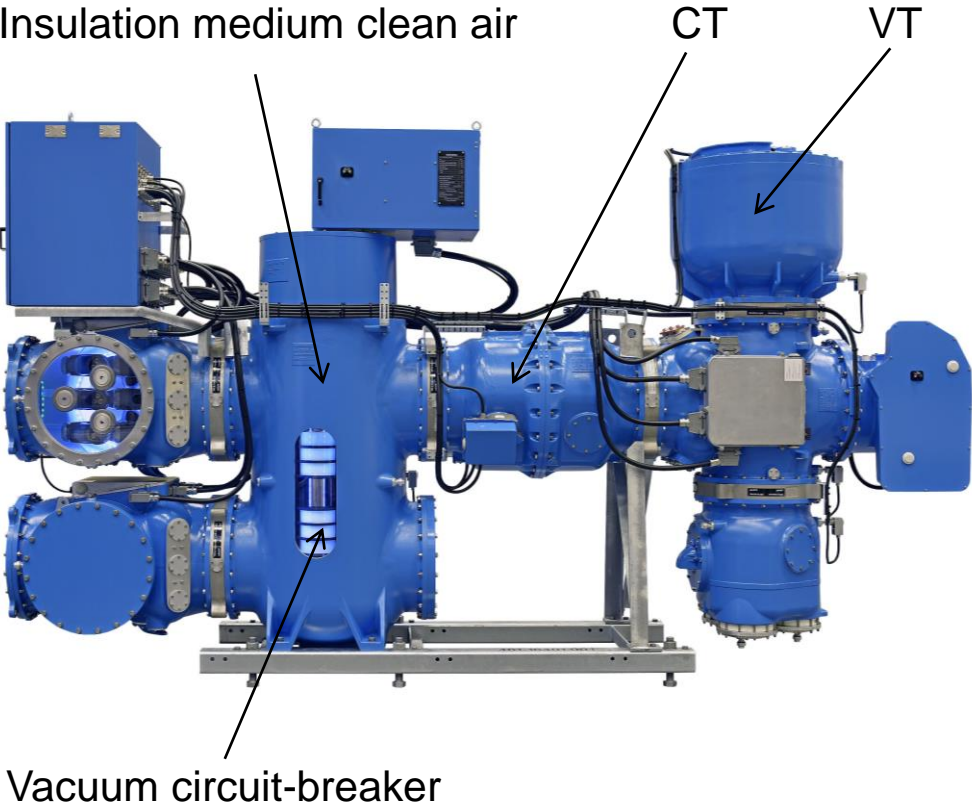


Gas-Insulated Switchgear 8VN1 blue GIS up to 145 kV / 40 kA

Technical data (with Conventional Instrument Transformer)



Switchgear type	8VN1	
Rated voltage	up to	145 kV
Rated frequency		50 / 60 Hz
Rated short-duration power-frequency withstand voltage (1 min)	up to	275 kV
Rated lightning impulse withstand voltage (1.2 / 50 µs)	up to	650 kV
Rated continuous current - busbar	up to	3150 A
Rated continuous current - feeder / bus coupler	up to	3150 A
Rated short-circuit breaking current	up to	40 kA
Rated peak withstand current	up to	108 kA
Rated short-time withstand current (up to 3 s)	up to	40 kA
Leakage rate per year and gas compartment (type-tested)		< 0.1 %
Driving mechanism of circuit-breaker		stored-energy spring
Rated operating sequence		O-0.3 s-CO-3 min-CO
		CO-15 s-CO
Interrupter technology		Vacuum
Insulation medium		Clean air
Weight of SF ₆ or other flourinated greenhouse gases		0 kg
GWP Global Warming Potential		0
CO ₂ equivalent		0 kg
Rated filling pressure		0,79 MPa abs
Bay width common pole drive		1000 mm
Bay hight, depth (depending on bay arrangement)		3200 mm x 5500 mm
Bay weight (depending on bay arrangement)		4.7 t
Ambient temperature range		-50 °C up to +55 °C
Installation		indoor / outdoor
First major inspection		> 25 years
Expected lifetime		> 50 years
Standards		IEC / IEEE
Other values on request		



Gas-Insulated Switchgear 8VN1 blue GIS up to 145 kV / 40 kA

Conventional - / Low Power - Instrument Transformer Technology

SIEMENS
Ingenuity for life

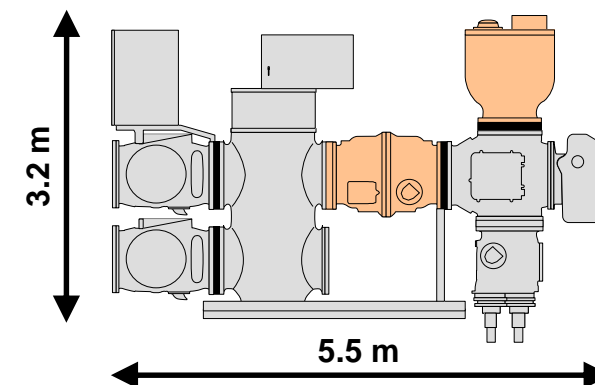
Instrument Transformer Technologie (Conventional)

Inductive Voltage Transformer (VT)



+

Inductive Current Transformer (CT)



Low Power Instrument Transformer (LPIT) Technology (Non-Conventional)



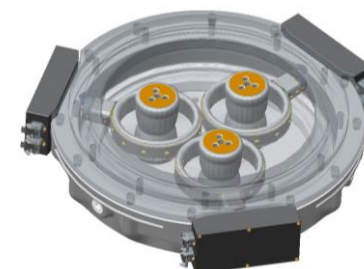
1 x Electric Field Probe
for Voltage Measurement

+

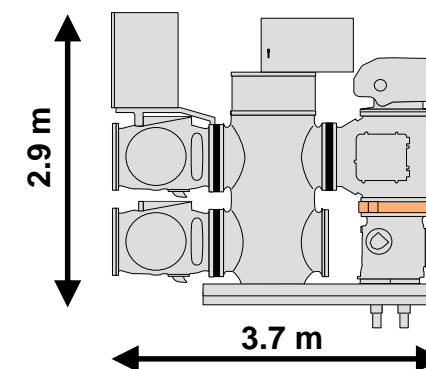


2 x Rogowski Coils for Current
Measurement (redundant)

=



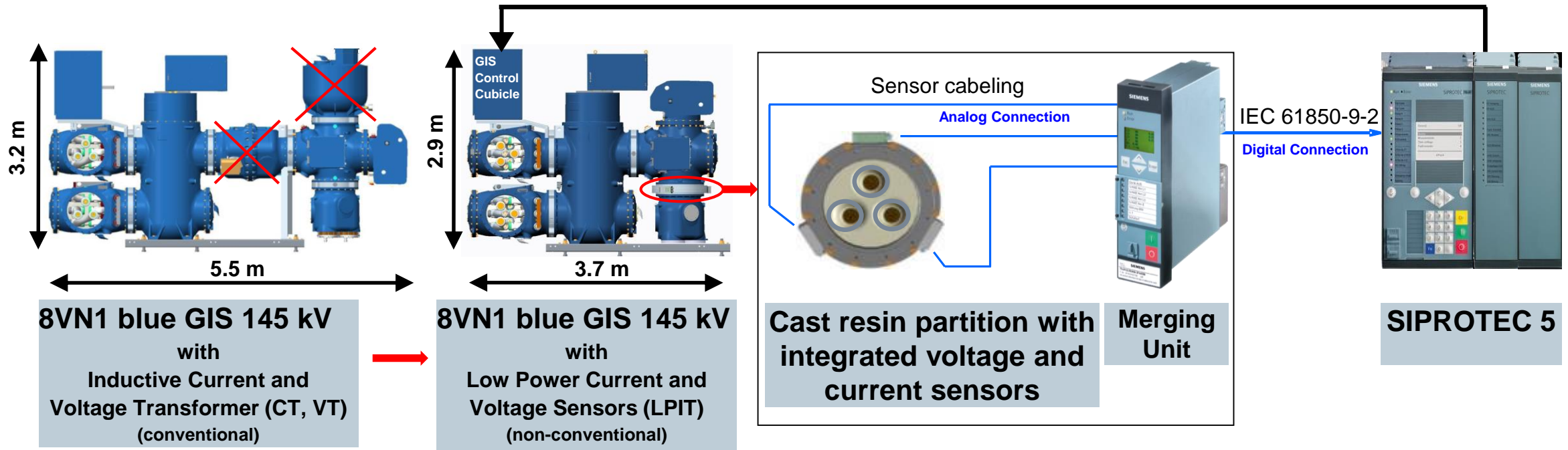
Cast resin partition with integrated
voltage and current sensors



Gas-Insulated Switchgear 8VN1 blue GIS up to 145 kV / 40 kA

Low Power Instrument Transformer (LPIT) - Technology

SIEMENS
Ingenuity for life



- **Combined electronic Voltage and Current Sensor (eVT/eCT)** according to IEC / IEEE
- Applied technologies: **Rogowski Coil & Electric Field Probe**
- **One common measuring system** für protection and metering

	realized		achievable
Current range:	100 A	up to 3.150 A; 100 kA	up to 6.000 A; 216 kA
Voltage range:	72.5 kV	up to 145 kV	up to 550 kV

References – Blue Products

45 bays in operation, 870 bays ordered



**72,5 kV
Blue Circuit Breakers, LT**
6 in operation in
FRA, LUX, DEN, AUS since 2010



**72,5 kV
Blue Circuit Breakers, DT**
3 ordered in USA



**72,5 kV
Blue GIS Wind**
4 in operation
in DEN since 2018
815 ordered in GBR, NDL, DEN, USA, TAI



145 kV Blue Circuit Breakers, LT
30 in operation in GER, POL
since 2018
15 ordered in NOR, SWE, GER,
SUI, GBR, POL, ROM, KAZ, USA



**145 & 245 & 420 kV Blue
Instrument Transformers**
2 x 145 kV and 3 x 245 kV in
operation in GER since 2018
14 ordered in NOR, SWE, GER
thereof 3 x 245 kV VTs and
2 x 420 kV VTs



145 kV Blue Circuit Breakers, DT
3 ordered in USA



145 kV Blue GIS
20 ordered in USA, 3 x NOR, ESP

● In Operation ● Ordered

Blue Products Referenz

Umspannwerk Nördlingen, Deutschland



Eine sichere, zuverlässige Stromversorgung und nachhaltigen Klimaschutz miteinander in Einklang zu bringen, ist technisch höchst anspruchsvoll. Während die Energieversorgungsunternehmen ihre Netze für die Energiewelt von morgen umgestalten, wächst zugleich der Bedarf an nachhaltigen, umweltfreundlichen Lösungen.

Die Siemens Lösung: Blue Products mit Vakuum-Schaltröhren und Isolation mit komprimierter Luft, sogenannte Clean Air

- Freiluft-Leistungsschalter mit Vakuum-Schalttechnologie und Clean Air Isolationstechnologie: 3AV1, 145 kV, 40 kA, 3150 A, -60°C bis 55°C
- Freiluft Strom- und Spannungswandler SVAA, 145 kV, -60°C bis 55°C

“Innovation und Umweltschutz sind für uns sehr wichtige Werte. Mit Siemens, unserem langjährigen Partner, verbinden wir genau diese Werte.”

Dr. Martin Konermann, Geschäftsführer Technik, NetzeBW

Next generation Circuit Breakers are Vacuum Circuit Breaker, when available for EHV

SIEMENS
Ingenuity for life



Source: Cigre Greenbook Switching Equipment, Springer 2018 & Cigre A3 T&D switching equipment tutorial, August 2018

Cigre 2018 Highlight: Vacuum Interrupters up to 245 kV and 63 kA for Siemens Blue Circuit Breaker & GIS up to 420 / 550 kV / 63 kA



Market requirements

- High reliability and high performance
- Easy operation and minimal maintenance
- Sustainable regarding environment, society and regulations

Solution

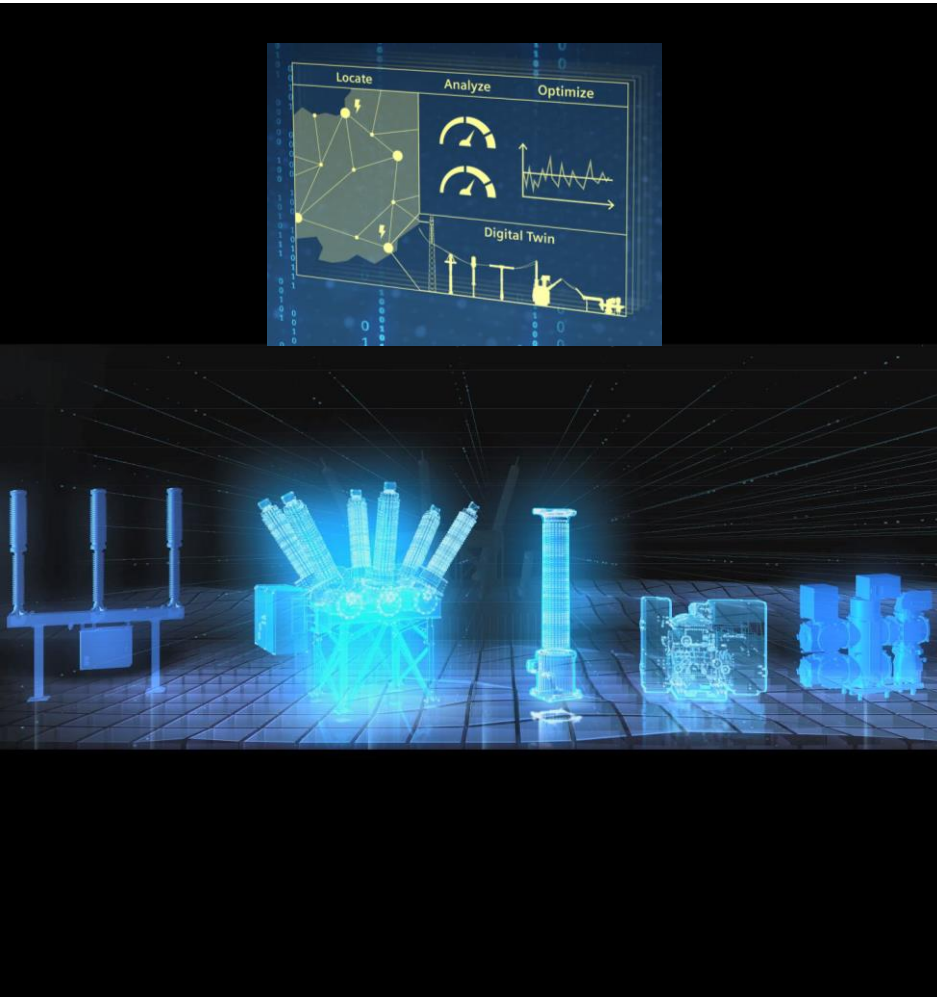
- Vacuum switching technology for high-voltage circuit-breakers and GIS up to 420 / 550 kV and 63 kA combined with clean air insulation.
- Exhibits: Vacuum-Interrupters for 170 kV / 50 kA and 245 kV / 63 kA

Customer benefits

- **High reliability** due to the hermetically tight vacuum interrupter, no decomposition products; extraordinary lifetime endurance
- **High performance:** Excellent interrupting performance at rated continuous and rated short-circuit currents throughout life-time of the vacuum circuit-breaker. Outstanding for frequent switching applications.
- **For all service conditions:** Perfect for low temperatures - No liquefaction of switching medium
- **No maintenance:** Maintenance free due to sealed for life technology
- **No CO₂e emissions:** Switching media (vacuum) with GWP=0; no CO₂e emissions during operation, maintenance or recycling

www.siemens.com/eco-transparency

Let us us jointly improve the sustainability of our transmission and distribution systems



Dr.-Ing. Dirk Helbig
Senior Principal High Voltage Products

Siemens AG
Transmission Products / Digital Enterprise
Freyeslebenstr. 1
91058 Erlangen

Mobil: +49 173 255 89 08

E-Mail: dirk.helbig@siemens.com

[siemens.com/transmissionproducts](https://www.siemens.com/transmissionproducts)
[siemens.com/eco-transparency](https://www.siemens.com/eco-transparency)

Disclaimer



Subject to changes and errors. The information given in this document only contains general descriptions and/or performance features which may not always specifically reflect those described, or which may undergo modification in the course of further development of the products. The requested performance features are binding only when they are expressly agreed upon in the concluded contract.

All product designations, product names, etc. may contain trademarks or other rights of Siemens AG, its affiliated companies or third parties. Their unauthorized use may infringe the rights of the respective owner.

- [2012-1] **S. Giere, R. Renz, F. Richter, N. Trapp**, "*Capacitive Current Switching Capability of 72.5 kV High-Voltage Vacuum Interrupters*", XXV International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV), Tomsk, p. 217-220, 2012
- [2012-2] **N. Wenzel, S. Kosse, A. Lawall, R. Renz, W. Hartmann**, "Numerical Simulation of Multi-Component Arcs in High-Current Vacuum Interrupters", XXV International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV), Tomsk, p. 321–324, 2012
- [2014-1] **CIGRE Technical Brochure 589**, "The Impact of the Application of Vacuum Switchgear at Transmission Voltages", Cigre 2014, ISBN 978-2-85873-287-6
- [2014-2] **T. Psotta, V. Hinrichsen, E. Kynast, F. Richter, Wethekam, S.** "Investigation on the conditioning of high-voltage vacuum interrupters", XXVI International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV), Mumbai, p. 1-4, 2014
- [2014-3] **N. Wenzel, A. Lawall, U. Schümann, S. Wethekam**, "Combined experimental and theoretical study of constriction threshold of large-gap AMF vacuum arcs", XXVI International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV), Mumbai, p. 193–196, 2014
- [2015-1] **J. Teichmann**, „Vakuumschaltröhren bei höheren Spannungen“ FKH – Fachtagung Hochspannungs-Leistungsschalter (Schaltgeräte), Rapperswil, 24. November 2015
- [2016-1] **N. Presser, C. Orth, B. Lutz, M. Kuschel, J. Teichmann**, "Advanced insulation and switching concepts for next generation High Voltage Substations", Cigré Session 2016, Paris
- [2017-1] **S. Kosse, P. Nikolic, G. Kachelriess**, "Holistic evaluation of the performance of today's SF6 alternatives proposals", CIRED Int. Conf., Glasgow, June 2017, paper 0819
- [2017-2] **B. Lutz, K. Juhre, M. Kuschel, P. Glaubitz**: "Behavior of gaseous dielectrics with low global warming potential considering partial discharges and electric arcing", Cigré Winnipeg Canada 2017 D1 Colloquium
- [2017-3] **B. Lutz, C. Orth, K. Juhre, N. Presser, M. Kuschel**, "Dielectric Performance of Insulator Surfaces in Clean Air for High Voltage Gas Insulated Switchgear Application", 20th Intl. Symp. on High Voltage Engineering, Argentina, August 2017
- [2017-4] **B. Lutz, M. Kuschel, P. Glaubitz**: "Future Challenges for the Grid - Integration of environment friendly gas-insulated substations", Cigré 2017 B3 Colloquium, Recife Brazil
- [2017-5] **Siemens Tech Topics** for users and specifiers of technical equipment.
Internet: https://www.downloads.siemens.com/download-center/Download.aspx?pos=download&fct=getasset&id1=BTLV_41965
- [2018-1] **J. Teichmann, S. Kosse, M. Koletzko, N. Wenzel, S. Giere, D. Helbig, U. Prucker, M. Engel, C. Wolf**, "*145/170 kV Vacuum Circuit Breakers and Clean-Air Instrument Transformers – Product performance and first installations in AIS substations*", Cigré Session 2018, Paris
- [2018-2] **M. Kuschel, C. Bradler, C. Bütüner, L. Hansen, A.-S. Bonde Mortensen, J. Gaard**, "*On-site experiences of 72.5 kV Clean-air GIS for Wind-turbine On- and Offshore application*", Cigré Session 2018, Paris
- [2018-3] **S. Giere, T. Heinz, A. Lawall, C. Stiehler, E.D. Taylor, N. Wenzel, S. Wethekam**, "X-Radiation Emission of High-Voltage Vacuum Interrupters: Dose Rate Control under Testing and Operating Conditions", ISDEIV International Symposium on Discharges and Electrical Insulation in Vacuum, Greifswald, 2018
- [2018-4] **S. Giere, T. Heinz, J. Teichmann**, "Capacitive Current Switching with HV Vacuum Circuit Breakers", Technical Report, Siemens 2018
- [2019-1] **T. Rak**, "PG&E phases out SF₆ greenhouse gas", T&D world, January 2019