

CIGRE Paris Session 2026

Key Takeaways SC A3



cigre

For power system expertise

Arnhem, 29-09-2026

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TenneT NL

Topics

- What took place in Paris Session 2026?
- SF₆ replacement and alternatives
- HV switchgears development and challenges
- Switchgears for specific application: HVDC, GCB, FCL
- Highlights from Study Committee A3
- Technical exhibitions
- Summary

What took place in Paris Session 2026 for SC A3?

- 113 papers SC A3 provides updates and challenges
- Group Discussions Meeting
- Workshops (SF₆ alternatives)
- Tutorials (Instrument Transformers)
- SC A3 meeting

- ❖ 64 presentations out of 113 papers
- ❖ 31 presentations on “Power equipment using SF6 alternatives”
- ❖ Topic on digital technology has 14 papers

SF₆ replacement and alternatives

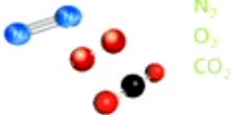
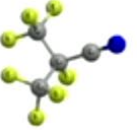
- Status on SF₆-free substation equipment
- Regulatory status in EU
- TSO perspective

Status on SF₆-free substation equipment

SF₆-free equipment, *Status per 25.08.26

MV, CB / LBS = medium voltage switchgear, circuit breaker / load break switch
 LT = live-tank
 DT = dead-tank
 GIS = gas-insulated switchgear
 GIL / GIB = gas-insulated lines / busbars



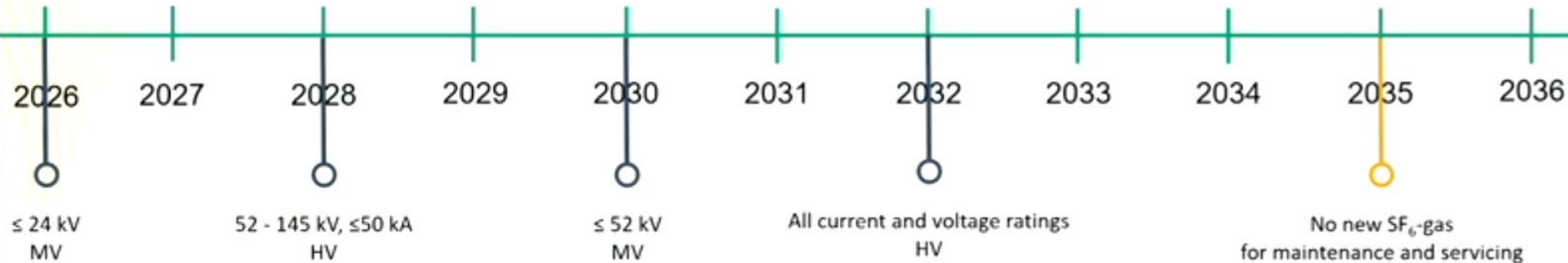
	INSULATION	INTERRUPTION	GWP	VOLTAGE*	APPLICATION
 SF ₆	SF ₆	SF ₆	24 300	12 – 1 200 kV	MV / LT / DT / GIS
Natural-origin gases 	N ₂ / O ₂ , solid	VACUUM	0	10 - 252 kV	MV CB / LT / DT / GIS
	N ₂ / O ₂	N ₂ / O ₂	0	420 kV	MV LBS, ≤ 24 kV
	O ₂ / CO ₂		<1	72 – 420 kV	GIB / GIL
	CO ₂		1	12 – 40 kV	LT
Fluoronitrile-based  C ₄ F ₇ N + natural-origin gases	C ₄ F ₇ N / AIR	VACUUM	300 - 750	10 - 40 kV	MV LBS
	C ₄ F ₇ N / CO ₂ / O ₂	C ₄ F ₇ N / AIR	300 - 750	72 – 550 kV	Distr / LBS / GIS
	C ₄ F ₇ N / CO ₂		300 - 750	170 kV	LT / DT / GIS
	C ₄ F ₇ N / CO ₂		> 500	1 000 kV	GIS
	C ₄ F ₇ N / N ₂		300 - 750	420 kV	GIB GIL

Regulatory status (EU)



Europe: Phase-out of new SF₆ equipment

- Deadlines for putting new SF₆ electrical switchgear “into operation”



- Some derogations. SF₆ OK if:
 - Equipment was ordered before 11 March 2024
 - No alternatives exist (in general or for that particular technical need)
 - Existing equipment is moved
 - (Some countries in Europe not in the EU have yet to implement the newest F-gas regulation)

Perspective TSO

Easier to slow down than to speed up

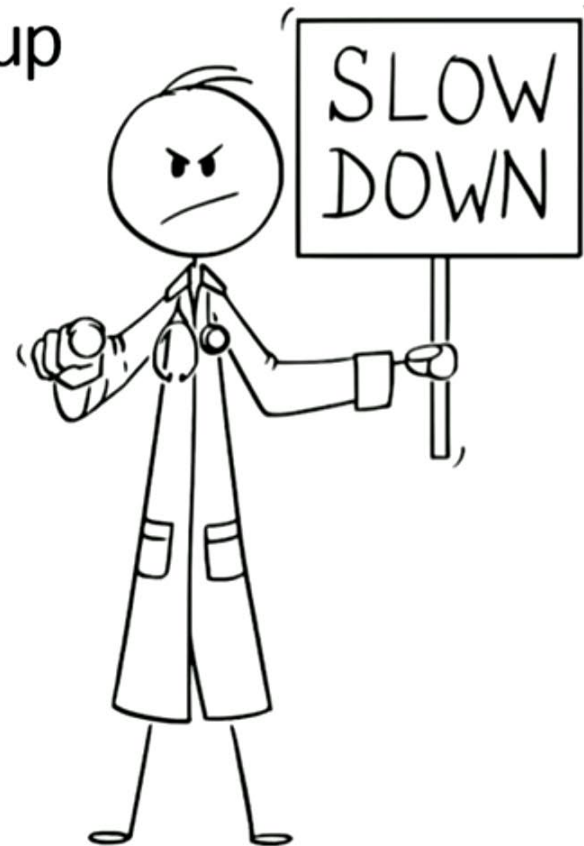
Many stakeholders inside TSO

- Safety: Toxicity C4FN not clear
- Environment: SF_6 became unpopular over time, what about alternatives in future? PFAS?
- Pricing: Which (higher) price is allowed (regulator?)
- Lifespan: Unknown at the start
- Footprint: Larger buildings, more (raw) materials? (LCA)
- Maintenance: Different mixtures per rating, installation and over time? Off-shore?
- Range: Different alternatives for different ratings?
- Future: Which alternative would be the best, still to come, keep on waiting?



Manufacturers need early adopters, TSO's need proven technology

Paris Session



GDM: Switchgears development and challenges

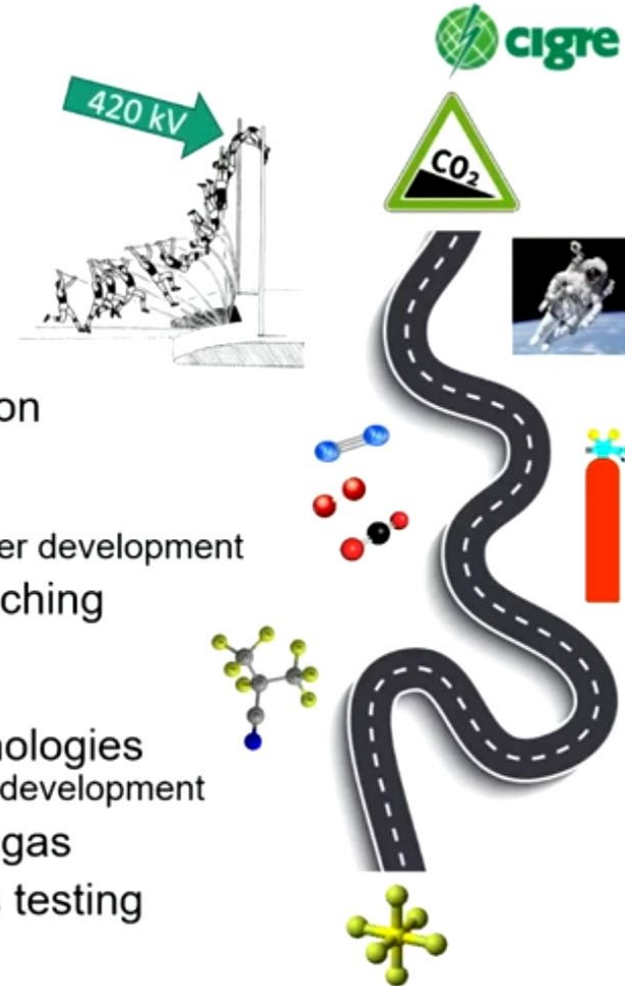
Group 1: Equipment using SF₆ alternatives

A3: 35 reports; B3: 7 reports; D1: 4 reports

CIGRE 2026: SF₆-free switchgear crosses the EHV bar

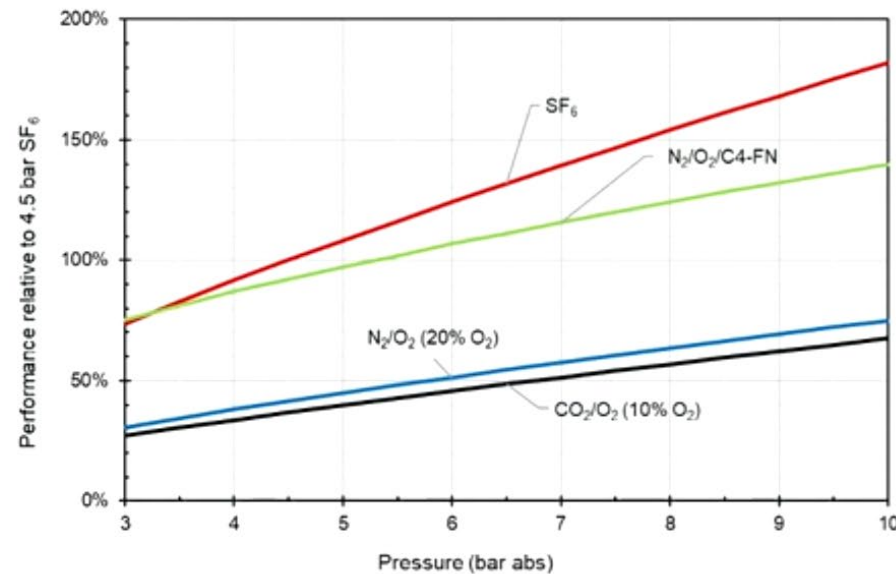
Three main technologies of SF₆ replacement co-exist:

- Natural origin gases CO₂/O₂ with 3.5-5% C4-FN addition
 - up to 550 kV 63 kA installed in GIS
- Natural origin gases CO₂/O₂ without synthetic addition
 - up to 420 kV 63 kA installed in live tank breaker; 300 kV GIS under development
- Natural origin gases for insulation and vacuum for switching
 - up to 420 kV 63 kA in live tank to be installed 2026
- Strong attention to shunt reactor switching for all technologies
 - Similar behaviour as SF₆, for vacuum mitigation measures are in development
- GIL/GIB refill projects reported with N₂ as background gas
- AI based component optimization now in practice, less testing



Switchgears development and challenges

Dielectric performance of 85% N₂, 5% O₂, 10% C4-FN vs. SF₆



Net ionization coefficient α_{eff}

Natural gas (e.g.
CO₂/O₂ or N₂/O₂):
 α_{eff} too high

adding a small
amount of C4-FN

CO₂/O₂/C4-FN
or N₂/O₂/C4-FN

Significantly lowered α_{eff}

Critical electric field strength increased

Dielectric performance increased

Switchgears development and challenges

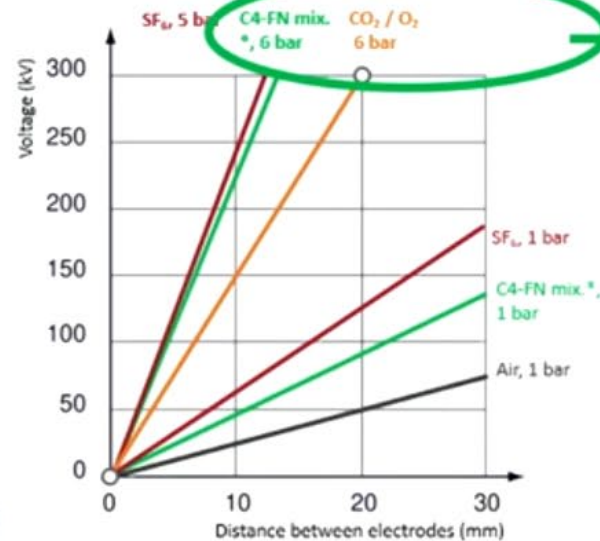
Criteria for circuit breakers :

Technical performance
Foot-print
Reliability



..also SC current
interruption &
temperature rise

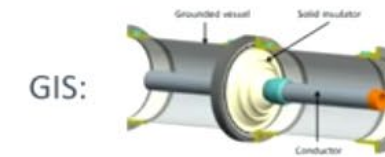
1/ Technical performance : Dielectric



* C4-FN mixture with 5% C4-FN, 13% O₂, 82% CO₂

→ CO₂/O₂ based mixture **with** C4-FN filled at 7,5bar same perf as SF₆

→ CO₂/O₂ based mixture **without** C4FN filled at 9,5bar close to SF₆



Live Tank:



By increasing the distance, the full rated voltage can be addressed

Switchgears development → retrofit (more in SC B3)

- Switchgear intended for SC current interruption can't be simply retrofitted with increase of the SF6-free gas pressure. More to be done.
- Retrofit on High-speed (making proof) ES to be done by replacing with another design of arcing contacts and increase of SF6-free gas pressure.
- Retrofit on DS/ES to be done by slight increase of SF6-free gas pressure. Manufacturers of C4FN type GIS claimed there is no need to change the design of the contact.

Challenges → *shunt reactor switching* (C4FN mix)

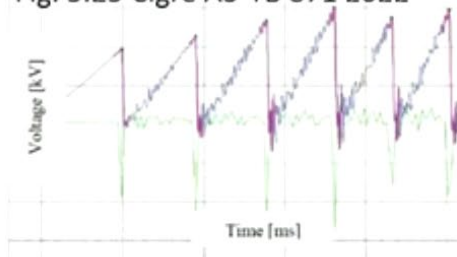
2. What mitigation technology is preferred in order to reduce the impact of (multiple) re-ignitions, controlled switching, snubber circuits or other?



- Answer – the preferred way is: **no additional equipment** – avoiding voltage escalation, and (energizing) overvoltages / inrush currents
- Gas circuit breakers can intrinsically handle these cases without additional equipment

Reactors

Fig. 5.25 Cigre A3-TB 871 2022



Risk: multiple high-frequency transients and voltage escalation

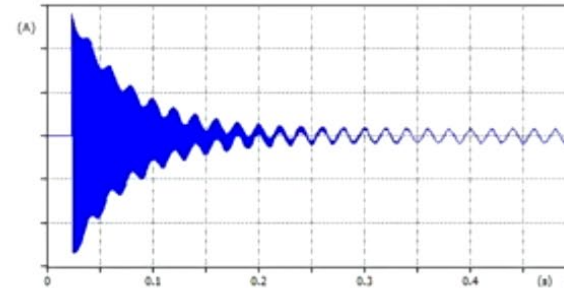
Cause: capability of the CB to interrupt high-frequency currents, chopping overvoltages exceeding dielectric strength even with controlled long arcing times, virtual current chopping

Consequence: damage of equipment, especially of shunt reactors

Mitigation measures: RC-snubbers, surge capacitors, surge arresters

Drawback of mitigation measures: cost, footprint, losses

Capacitor banks / Transformers



Risk: high inrush currents

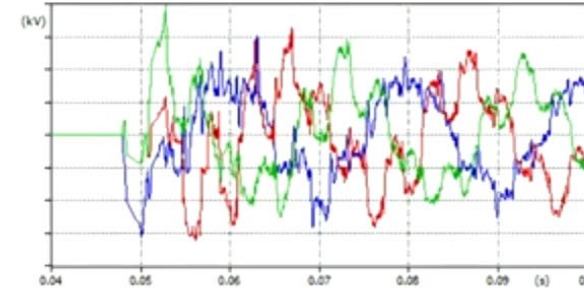
Cause: relatively high scatter of the dielectric strength of the CB

Consequence: CB contacts erosion and impaired dielectric performance, voltage distortion, nuisance protection trip

Mitigation measures: inrush current limiting reactors (for capacitor banks), pre-insertion resistors

Drawback of mitigation measures: cost, footprint, losses, complexity of asset management

Lines / Cables



Risk: high overvoltages

Cause: low arc-voltage of the CB

Consequence: damage of equipment

Mitigation measures: Pre-insertion resistors, surge arresters

Drawback of mitigation measures: cost, complexity of asset management

Challenges → shunt reactor switching (VCB)

Advantages of RC-Filter for VCB shunt reactor switching applications



Setup and configuration

- Typical configurations are selected by RC configuration tool
- No single-pole drive is required
- No point-on-wave (POW) control unit is required
- No commissioning of controlled switching is required
- Decades of experience in MV grid applications

Robust passive mitigation

- Passive compensation with low operational complexity
- Calculated MTTF* > 100.000 years
- Expected service life > 40 years
- First 123/145 kV applications have been in successful service since 2022

→ RC filters provide a robust alternative to controlled switching solutions for mitigating multiple re-ignitions in SF₆-free VCB shunt reactor applications.

* Mean Time to Failure is based on MV



Indoor application: RC-Tower and shunt reactor

Challenges → shunt reactor switching (low current)

Are the IEC 62271-110 test current levels for shunt reactor circuit-breakers appropriate?



- Survey carried out using the Brazilian system operator's (ONS) database:

System Voltage (kV)	Nr. of reactor banks		Reactor switching current statistics			
	Total	Switchable	Min.	Max.	Accumulated frequency of standard testing currents coverage	
			(A)	(A)	Ireact. < 100 (A)	Ireact. < 315 (A)
230	266	136	13	251	91%	100%
345	26	23	84	221	4%	100%
440	37	37	118	262	0%	100%
500	749	329	58	289	7%	100%
765	20	5	125	249	0%	100%
Total	1098	530	13	289	28%	100%

Lower current ~
higher TRV

Suggested to
take lower
current in the
IEC

Challenges → *NOG for metal enclosed switchgear (GIS)*

2. What are the technical obstacles of GIS/DTB using NOG?



(1) Low Dielectric Strength and High filling pressure

- The dielectric strength of natural origin gases is only **about 40% to 45% of SF6**.
- Filling pressure must be significantly increased (**8 ~ 10 bar or higher**), enclosure diameter must expand by **30% to 50%**.
- High operating pressures also raise manufacturing costs and increased enclosure wall thickness.

(2) Thermal Degradation and Deficient Arc Quenching Performance

- Compared to SF6, NOG exhibit lower thermal conductivity and slower dielectric recovery in the arc-zone.
- Due to low withstand level of TRV(Transient Recovery Voltage) following high-current interruption (50 kA / 63 kA), **optimization of the nozzle and compression efficiency improvements in Puffer mechanisms** are imperative.

(3) Increased Operating Mechanism Energy

- To compensate for lower breaking capability, opening speeds must be increased, or **multi-break must be applied**.
- This increases the **operating mechanism drive energy requirement by 2 times or more** compared to SF6 breakers, creating challenges in mechanical reliability, vibration control, and noise suppression.

(4) Sensitivity to Metallic Micro-particles and Electric Field Inhomogeneity

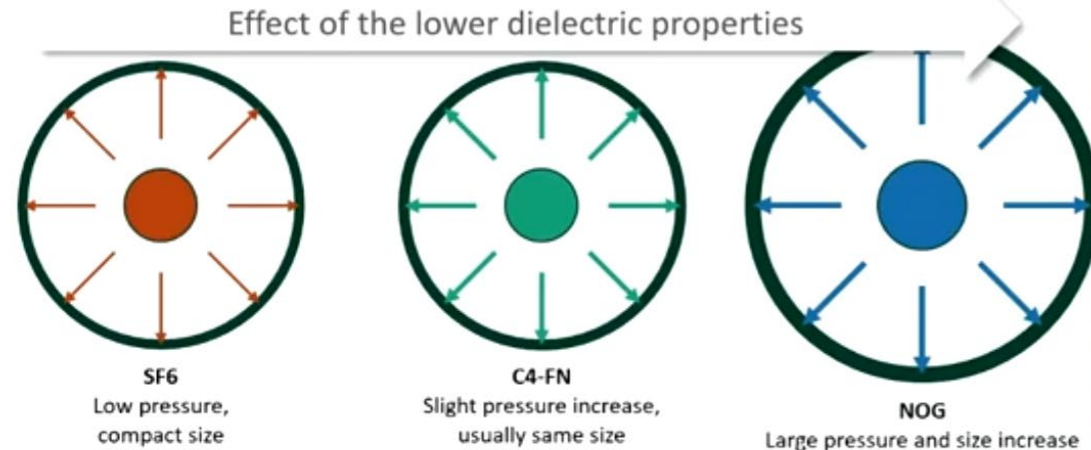
- **Sensitivity to Partial Discharge(PD)** due to metallic particles between live parts and the tank is higher than in SF6.
- Dielectric breakdown strength degrades noticeably in non-uniform electric field regions, **requiring spacer geometry optimization and advanced particle trap design**.

Challenges → NOG for HV GIS

Technical challenges

#1 - Withstand of internal pressure

- The main challenge is due to the **increase of internal pressure**
- It additionally combines with the increase of size (= more surface where the pressure applies)
- Enclosure thickness is not given to burn-through but for pressure withstand



Force = Pressure x Surface → Bigger dimensions requires stronger enclosures!

Example of for a tubular enclosure:

- SF₆ / C4-FN: Aluminium tube, Do=500mm, 15mm thickness
→ 61.9 kg/m
- NOG: Aluminium tube, Do=600mm, 19mm thickness
→ 94.0 kg/m, **+52% aluminium**

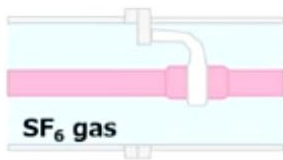
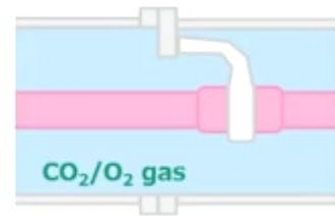
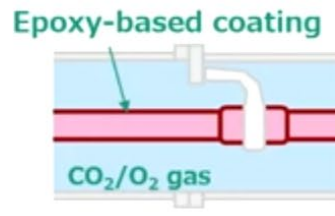
In AIS, composite insulators can withstand extremely high pressures and have no phase-to-earth distance, the problem is for GIS / DT

Challenges → NOG for HV GIS

Dielectric Technologies Limiting GIS Size Increase



➤ Key Technologies for Compact GIS

Insulating gas	SF ₆	CO ₂ /O ₂	CO ₂ /O ₂
Gas pressure	0.45 MPa-g	0.9 MPa-g	0.9 MPa-g
Applied technology	-	Natural origin gas (30 vol% O ₂) Higher gas pressure	Natural origin gas (30 vol% O ₂) Higher gas pressure Conductor coating
Key points	-	• CO₂/O₂ gas selected • Higher gas pressure within design constraints • Optimised O₂ concentration	• Newly developed conductor coating • Performance improved close to the theoretical potential
Equipment size ratio to SF ₆	100%	125%	110%
Configuration	 SF ₆ gas	 CO ₂ /O ₂ gas	 Epoxy-based coating CO ₂ /O ₂ gas

Challenges → *NOG for HV CB with VI*



Pros and Cons of Vacuum Interrupter Technology



Same footprint vs SF₆



Slightly larger footprint vs SF₆

Key features 420 kV

	Vacuum CB / GIS	SF ₆ CB / GIS
Number of short-circuit current interruptions (63 kA)	30	10 - 12
Switch-off time	2 cycles	2 cycles
Number of nominal current interruptions	10,000	6,000
Filling gas pressure relative	0.8 MPa	0.7 / 0.56 MPa
Ambient operating temperature	-50°C...+55°C	-30°C ...+55°C
Mass of fluorinated greenhouse gases		53 kg / 800 kg
Mass of CO ₂ equivalent	0 t	1,245 t / 19,440 t

Optimized for sustainability and performance: GWP-zero N₂/O₂ insulation gas, enhanced switching capability, and simplified gas handling without toxic decomposition by-products

How *reliable* is this SF6-free switchgear?

Experience from type testing SF6-free technologies



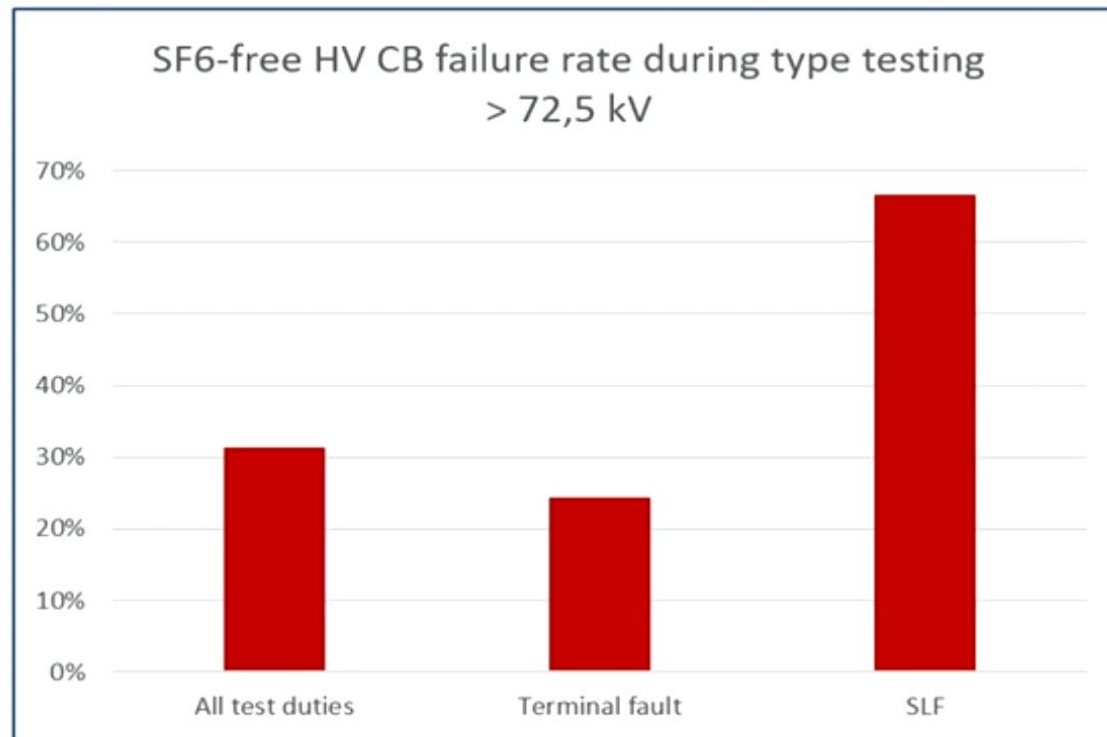
- In the recent year about 10 manufacturers have type tested SF6-free technologies of HV circuit-breakers for short-circuit and switching conditions
- Both GIS and AIS versions have been tested
- Tested technologies include combinations of C4-FN- O2- CO2, vacuum and natural origin gases
- In general more failures than in SF6 CBs were observed :
 - due to dielectric breakdowns after interruption
 - higher percentage of failures during SLF test duties – require parallel capacitance in many cases
- No design has qualified in our labs for a type test certificate, until now



Testing experience point towards need for specially designed electrical endurance tests to demonstrate the design adequacy of the new technologies.

How reliable is this SF6-free switchgear?

Experience from type testing SF6-free technologies



Switchgear for “specific” application: GCB – SF6

Generator circuit-breaker selection



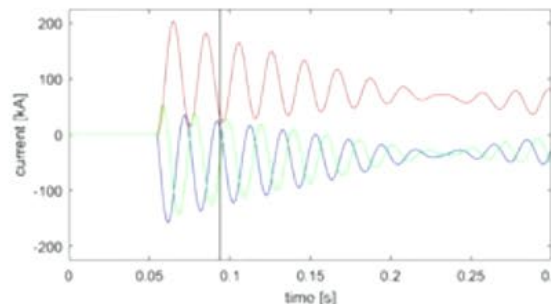
Example of Synchronous condenser in Europe (80 MVA/21 kV)

Extreme stresses on GCB

- Continuous current up to 50,000 A
- Short-circuit current up to 300 kA
- Steep transient recovery voltage
- Interruption of fault current with delayed or missing zero crossing after contact separation
 - Generator-source faults
 - Synchronizing under out-of-phase conditions

Prospective 90° out-of-phase current

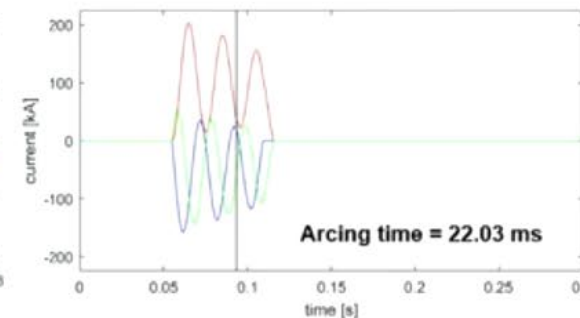
(Fault initiation at UA = 0)



Fault current at contact parting time ($t = 38.5 \text{ ms}$)

- Symmetrical: **54 kArms**;
- Degree of asymmetry: 129%

Interruption with SF6 GCB



Arcing time = 22.03 ms

It is not sufficient to select a GCB with symmetrical and asymmetrical short-circuit current ratings exceeding the application requirement, such ratings alone do not guarantee successful interruption of fault current with DCZ.

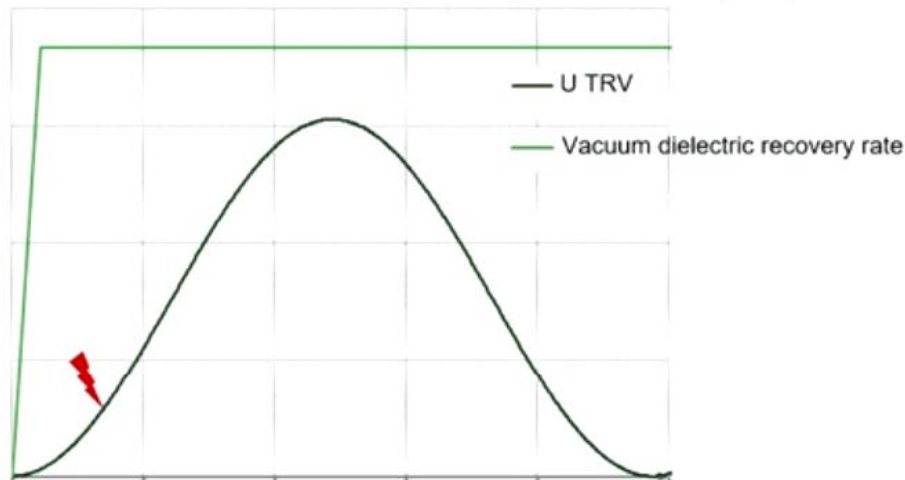
Suitability of GCB must be verified with the application-specific studies performed considering breaker-specific arc-voltage model. The resulting arcing time must remain within the maximum tested arcing time of the circuit-breaker.

Switchgear for “specific” application: GCB - VI

Reduction in fault stress



- Vacuum in medium voltage is a well-established and well proven switching media, both in distribution and generation applications.
- Being an excellent interruption media with a very fast recovery strength and low contact erosion, vacuum is becoming a preferred solution when dealing with high numbers of (fault) current interruptions or high transient recovery voltage is expected.



Transformer rating MVA	Prospective TRV		
	Time t_3 μs	TRV peak value u_c kV	RRRV kV/ μs
10 – 50	$0,58 U_i$	$1,84 U_i$	3,2
51 – 100	$0,53 U_i$	$1,84 U_i$	3,5
101 – 200	$0,46 U_i$	$1,84 U_i$	4,0
201 – 400	$0,41 U_i$	$1,84 U_i$	4,5
401 – 600	$0,37 U_i$	$1,84 U_i$	5,0
601 – 1 000	$0,34 U_i$	$1,84 U_i$	5,5
1 001 or more	$0,31 U_i$	$1,84 U_i$	6,0

The time delay t_0 shall be equal to 1 μs .

No additional
Capacitor
needed

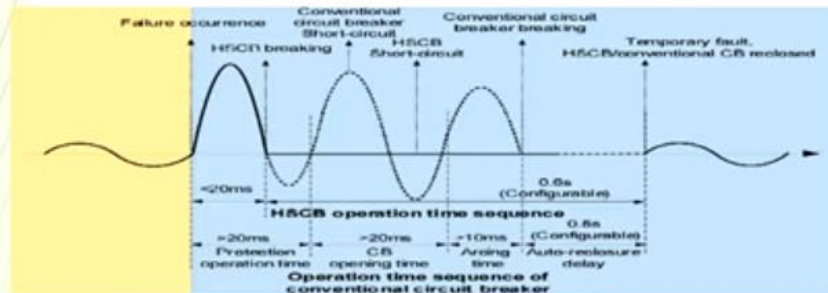
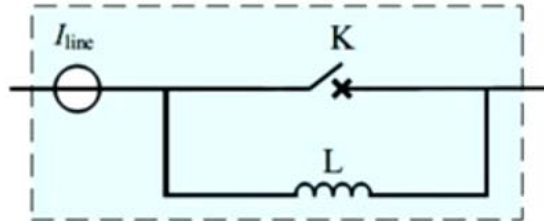
- Field experience has shown that vacuum switching technology has fulfilled its tested switching capability/current limiting level and beyond, being operated as master breakers in test laborites (extreme high numbers of fault current interruptions), usage in pump storage power plants (extreme high number of load current interruptions & low frequencies) and also its employment in railway applications.

Switchgear for “specific” application: *FCL in AC*

Background



Fast-switching FCL has been developed to mitigate increasing short-circuit current levels in modern transmission networks. It combines a high-speed mechanical switch with a current-limiting reactor that is inserted only after fault detection. Operational experience has been accumulated from more than 50 installations across China, Indonesia (world's first 500 kV installation), Bangladesh, and other countries, covering voltage levels from 10 kV to 500 kV with fault current ratings from 31.5 kA to 63 kA.



550kV
Fast-switching FCL



252kV
Fast-switching FCL



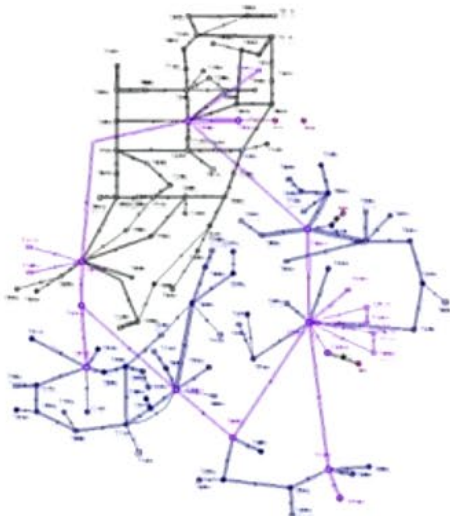
126kV
Fast-switching FCL

Switchgear for “specific” application: FCL in AC

System Impact Analysis

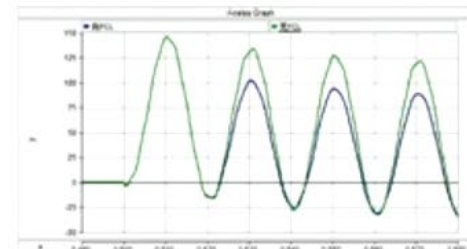
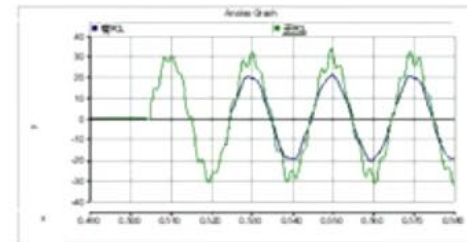
Impact on Power Flow

- 1) The FCL is inserted only after a fault occurs. Under normal operating conditions, system power flow distribution is not affected, causing no power flow issues.
- 2) After FCL insertion, Additional operating flexibility becomes available — for example, existing hot-standby lines can be put into service, improving system reliability.



Impact on Current Zero-Crossing

- 1) The current-limiting reactor is inserted at the current zero-crossing point. For the branch where the FCL is installed, The current zero-crossing instant remains practically unchanged, with no observable zero-crossing shift.
- 2) For non-faulted 220 kV lines, FCL insertion does not reduce the short-circuit current flowing through those branches and does not affect normal circuit breaker interruption.

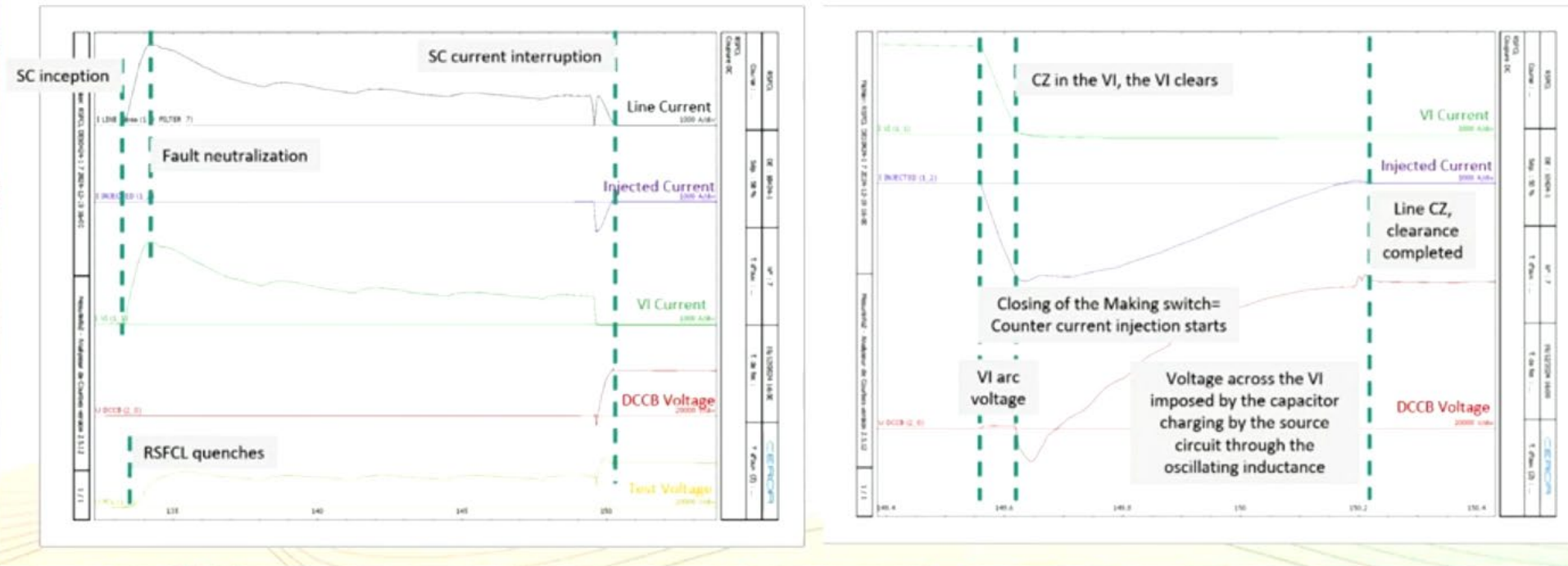


Switchgear for “specific” application: *FCL in DC*



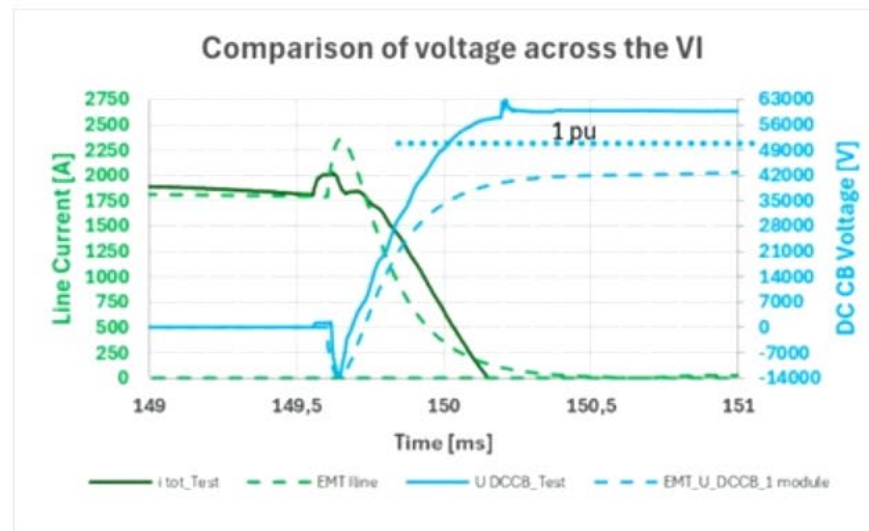
Description of the limitation and interruption process

- Focus on the interaction phase between Vacuum Interrupter and circuit



Switchgear for “specific” application: FCL in DC

Comparison of the VI voltage stress: test circuit versus MTDC grid simulation



➤ Conclusion

- The pseudo DC source can meet the VI voltage requirements
- The initial reverse peak is met
- Peak TIV is more severe but remains very low because of the RSFCL as expected: this one of the advantages of the RSFCL to dissipate the magnetic energy of the circuit
- The direct circuit can be used for unit testing typically upto 200 kVdc

Switchgear for “specific” application: *HVDC testing*

1 What testing methods for HV DC switching equipment?

DC current

2 Test method for rapid auto-reclosing of DC circuit breakers using an AC short-circuit generator

Switchgear for “specific” application: HVDC testing 1

HV DC power test lab - Requirements



Accurate representation of network conditions during HV DC circuit breaker testing:

- Interruption tests require absorption of large amounts of energy
→ only **direct** tests are suitable
- Necessary energy absorption is set by adjusting DC reactors
→ right amplitude & duration of transient interruption voltage **in the same** shot
- Seamless transition from TIV to the DC recovery voltage
→ By nature, the power source subsequently applies the **proper DC recovery voltage**
- Multiple interruption & reclosing with arbitrary durations
→ generator **always ready** to deliver the necessary energy
- Full pole vs reduced voltage testing possible
→ power source to adjust for **type** tests & **sub-assembly** tests
 - ❖ only adapted for switchgear with **series-connection** of **identical** modules

Switchgear for “specific” application: HVDC testing 1

Master Breaker

3-ph

Make Switch

L, R

Rectifier

L_{DC}

Test Object

HVDC power test lab
Key components

Up to 200 kVdc, 40kA peak, 20kAdc

Adjustable multi-MJ magnetic energy
(> 10 MJ)

Switchgear for “specific” application: HVDC testing 2

Breaking test methods of the DC-CB



- AC short-circuit generator methods can reproduce the necessary stresses for wide range of voltage levels and various types of DC-CBs.
- Rapid auto-reclosing test (O-t-C-t'-O) is required by IEC TS 62271-313, but the testing method has not been established.
=> Rapid auto-reclosing test method of a DC-CB using an AC short-circuit generator has been studied.

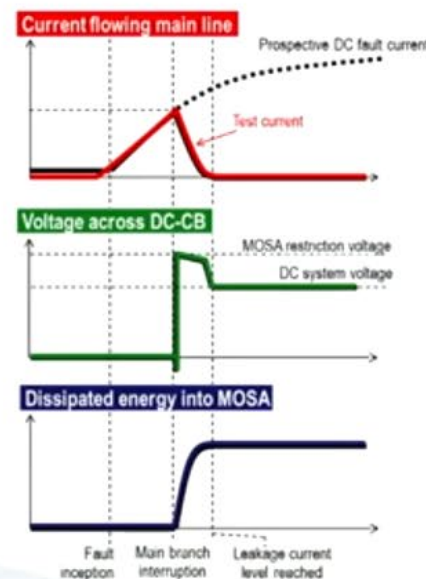
◆ Study procedure

<Step 1>

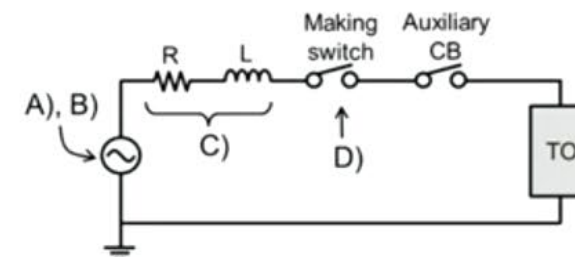
Proposal of auto-reclosing time “t” between first current and second current

<Step 2>

Study of the breaking test method and validation



<DC-CB main stress>



- A) AC short-circuit generator source frequency;
- B) AC short-circuit generator source voltage;
- C) Impedance (source and additional)
- D) Making phase angle

<Circuit of the AC short-circuit generator method>

Digital technology

- Digital twin
- Use of AI in monitoring and diagnostic
- Use of AI in switchgear development

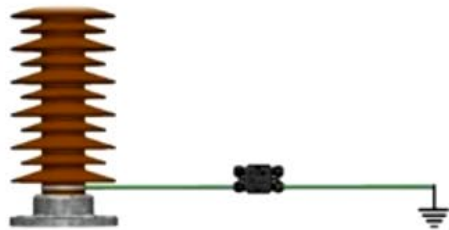
Digital technology

Avoided failure example: pollution flashover and insulator ageing



The attached work provides a practical prediction case: leakage-current amplitude and peak frequency are converted into intervention levels for AIS insulators.

Risk curve from laboratory data



sensor and monitoring ecosystem

Porcelain

Safe

$I_h < 250 \text{ mA}$
Risk < 10%

Attention

250-500 mA
Risk not negligible, especially with high frequency > 1 kHz

Intervention

$I_h > 500 \text{ mA}$
Very high risk, action such as washing

HTM / composite / RTV

Safe

$I_h < 10 \text{ mA}$
Stable I_h : limited ageing expected

Attention

$I_h < 100 \text{ mA}$

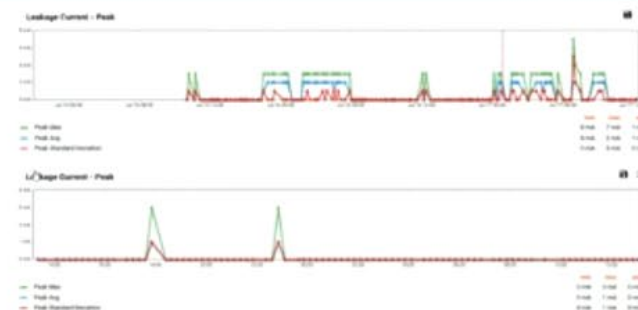
Intervention

$I_h > 100 \text{ mA}$
Increasing I_h and frequency: significant ageing

Contribution answer

This is an example of a model-based prediction that can avoid a critical outage: intervene before flashover risk becomes unacceptable or before HTM ageing accelerates.

The level of maturity of the twin in line with IEC 30186 is ML3 with AI can reach ML5

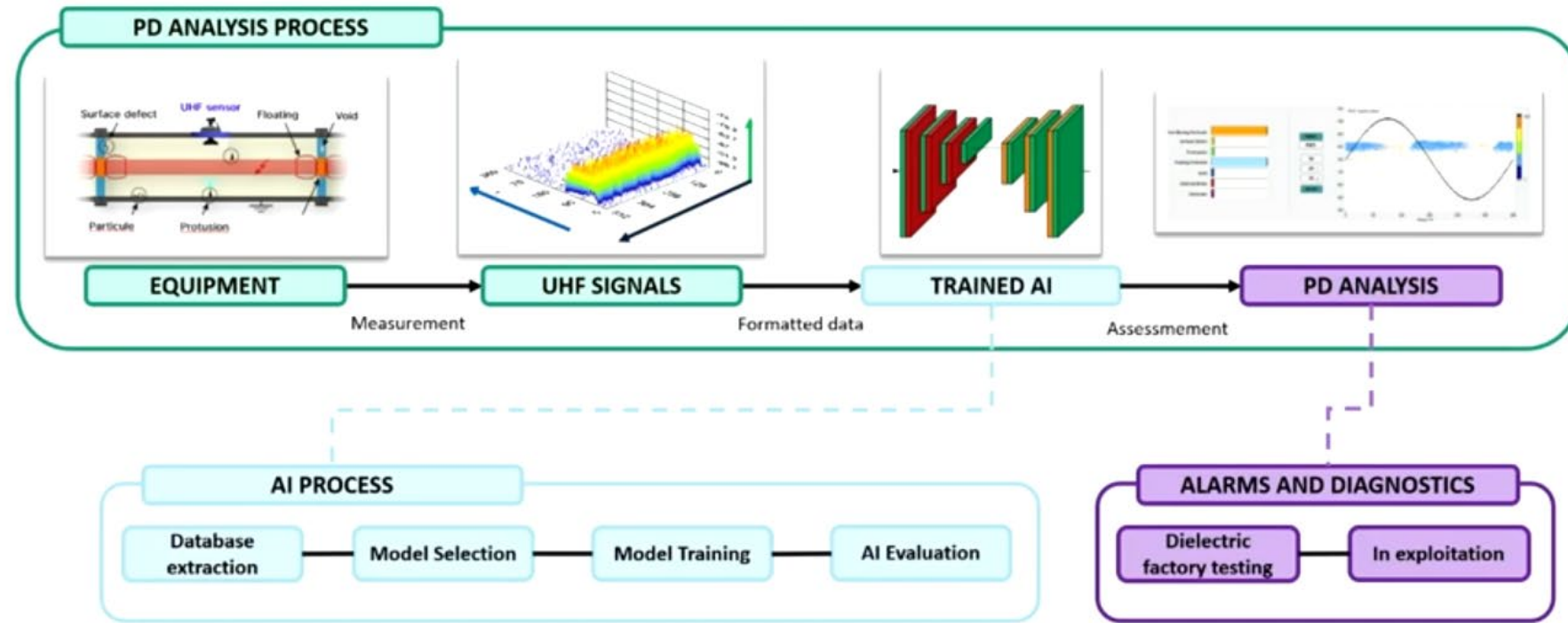


Before cleaning

After cleaning

Digital technology

AI for PD online monitoring



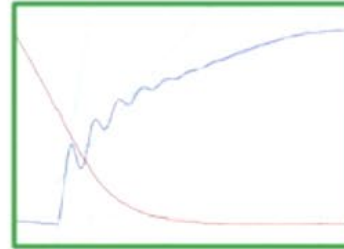
Digital technology

AI for circuit-breaker development

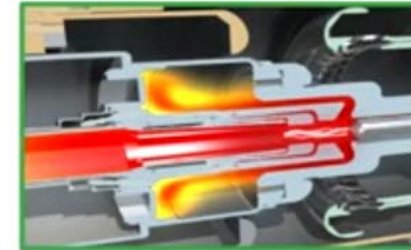
AI leverage >700 historical test data to predict the **outcome performance** of SF6-free high-voltage circuit breaker test based on:

- **Test parameters:** voltage, current, arcing time ...
- **1D simulation outputs:** temperature, pressure, flow-related indicators...
- **Geometrical parameters:** dimensions of key parts, internal volumes...

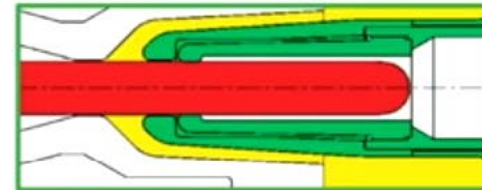
Test parameters



Simulation outputs



Geometrical parameters



- For low current, high current (short line fault and terminal fault)
- On dead tanks, live tanks and GIS Circuit-Breaker
- With g3 (Dead Tank and GIS) and CO2O2 (Live Tank)

Our **AI models** are able to predict the test results with high success rate

Instrument Transformers: experience on LPIT



Major findings on LPIT reliability and stability

Electronic IT

- **GIS LPIT:** Primary convertor including electronics are normally mounted on the GIS enclosure, VFTO-induced EMC interference is the most frequent issue, caused by the operation of switches, introducing distorting sensing signals and measurement results.
- **AIS LPIT:** Laser based power supply is applied since primary convertor is mounted on the high voltage end of the insulator, biggest concern is the aging and failure of the laser system. Thermal stress degrades laser diodes, lowering optical power and triggering measurement drift.

Optical CT (DCCT, AIS) (sorted by frequency of occurrence)

- **Temperature Factors:** Temperature variation alters the Verdet constant, induces stress linear birefringence and $\lambda/4$ waveplate phase drift, resulting in ratio and phase error drift.
- **Mechanical vibration:** Vibration from CB operation generates time-variant birefringence, polarization coupling and phase noise, causing measurement fluctuation.
- **Optical component ageing:** Active optoelectronic devices including SLD, PIN-FET photodetectors and phase modulators degrade over time, rising optical loss and accuracy degradation.
- **PD in the composite insulator:** PD triggered by insulation defects erodes embedded fiber and forms microcracks. Increased loss or fiber breakage leads to optical fiber failure.

Instrument Transformers: improvement on LPIT

Expected impact: a more compact, integrated partition



- The models allow the partition geometry to be **optimised so that dielectric and mechanical requirements are balanced** rather than treated in isolation.
- As a consequence, the partition can be dimensioned more efficiently, **reducing its thickness**.
- For an already integrated instrument-transformer partition, this optimisation makes the component **even more compact**.
- In the current (second-generation) developments for LPITs, the integrated partition can be brought close to the **envelope of a standard partition**, increasing the flexibility for the substation bay layout.

Generation 1
(97 kg, 2018)



Generation 2
(42 kg, 2026)



Study Committee A3 meeting

- ❑ Progress update on active working groups
- ❑ Preferential subjects for Cigre Paris Session 2028
- ❑ SC A3 in 2027

CIGRE Symposium Heidelberg 2027

One Grid – Technological Innovations for Integrated Power Systems

— Heidelberg, Germany · April 27–30, 2027 —

CIGRE A3&B3 Joint Colloquium 2027

Tokyo, Japan, 25th October - 29th October 2027

STUDY COMMITTEE SCA3

PS1 : T&D Equipment for the One Grid Transition

- Integrated equipment solutions supporting coordinated transmission and distribution network development
- Innovative technologies enabling accelerated grid expansion, increased transfer capability and system flexibility
- Applications and operational experience of equipment for HVDC, MVDC and hybrid AC/DC grid architectures

PS2 : Sustainable and Resilient T&D Equipment

- Field experience with SF6-free technologies and responses to environmental regulations
- Circular economy approaches including refurbishment, reuse and sustainable material utilization
- Enhancing equipment resilience against climate impacts, extreme weather events and supply chain challenges

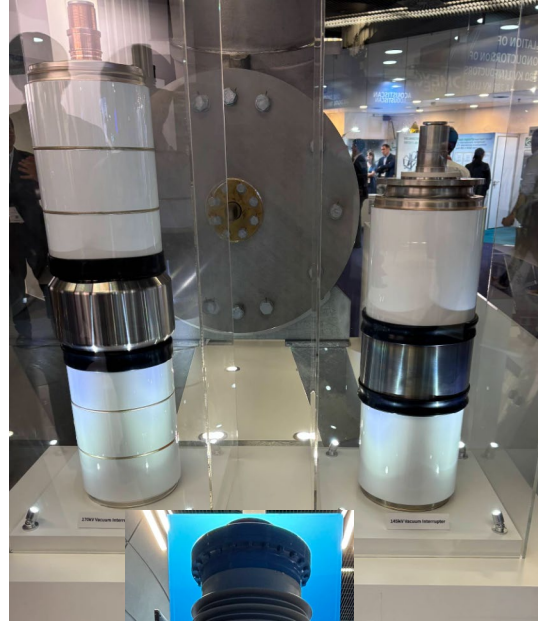
PS 3: Digital Asset Management and AI-enabled Decision Making

- Advanced monitoring, diagnostics and condition assessment using sensors and smart devices, and their integration into the equipment design
- Data governance, interoperability and lifecycle information management for T&D assets, application of Digital Twins, Artificial Intelligence and predictive analytics for asset management decision-making
- Applications and operational experience of coexistence of inductive and low-power instrument transformers: new challenges and opportunities offered by the digital framework

Technical exhibitions A3: new in Session 2026

- SF₆-free switchgears both AIS and GIS, from EU and Asia (JP, KR, CN).
 - ❖ 420kV – 63kA GIS using 4x VI → EU
 - ❖ 420kV – 80kA AIS LT CB using CO₂/O₂ → EU
 - ❖ 170kV – 63kA Vacuum Interrupter → JP
- HVDC system: converters incl. DC CB & switches (mock-up)
- Instrument transformers: DC measurements, SF₆-free IT, LPIT

Technical exhibitions A3: new in Session 2026



Summary

- EU regulation on F-gas → rapid growth of SF₆-free switchgear
- Development & challenges:
 - GIS using NOG for insulation and interruption
 - Small inductive switching still a challenge for switchgears
 - Retrofill
 - Use of coating inside the GIS to improve the dielectric properties
- Not much time to experience in real life → heavily dependent on testings
- What to be expected in Cigre Session 2028:
 - Next development and experiences on SF6 alternatives switchgear
 - Hope to see more on DC switchgears
 - More advance digital technology

Thank you for your attention!

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