# Replacing SF6 in high voltage circuit breakers

One target: reducing CO2 equivalent factor

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CIRCUIT BREAKERS CLEAN GRID
SF6-FREE SOLUTIONS

*While $SF_6$ is widely used in power transmission, allowing manufacturers to design reliable, safe and compact equipment, its $CO_2$ equivalent factor is becoming more and more of an issue. For this reason, some countries, such as Sweden or New Zealand, are increasingly focusing on $SF_6$-free solutions. Alstom already monitors $SF_6$ throughout the production chain and the emissions of its products are particularly low. On top of this, the company has taken the initiative of developing a new range of 100 % $SF_6$-free circuit breakers based on vacuum technology, starting with the VL109 for 72.5 kV.*

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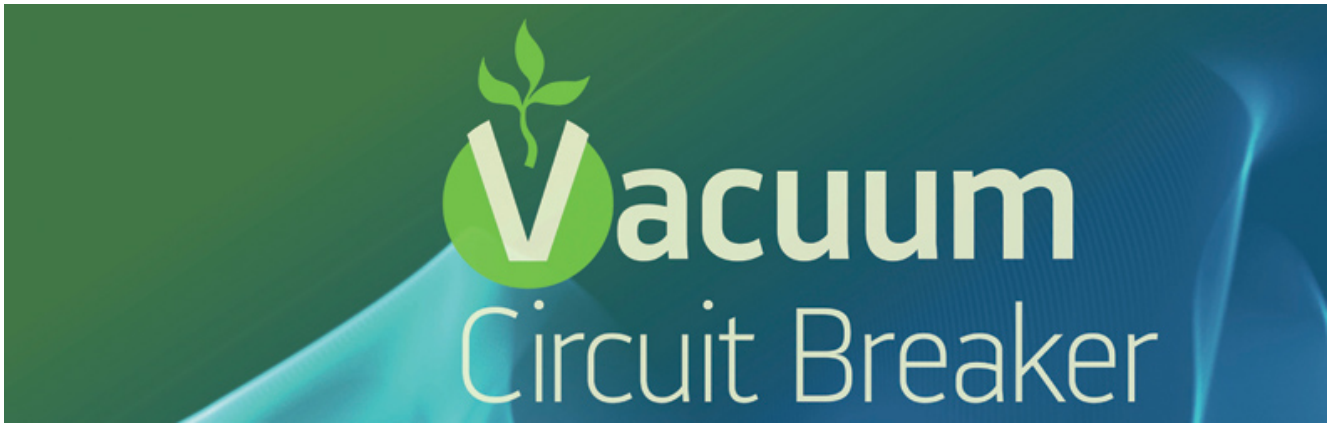
Almost all modern high voltage circuit breakers running at transmission voltage levels employ sulphur hexafluoride ($SF_6$) as an arc-extinguishing medium for current interruption and for dielectric insulation between the terminals. This is because of the excellent interrupting capabilities of $SF_6$, combined with a high dielectric withstand. However, $SF_6$ is a greenhouse gas with high global warming potential.
Several countries have initiated policies to ban or limit its use. Anticipating this trend, Alstom has worked on a solution to provide a high voltage circuit breaker with no $SF_6$. The most promising approach is the use of vacuum technology for interruption, already used in medium voltage applications for decades and now almost universal at that level.



Vacuum interrupter layout.

## 1__Raising vacuum technology from MV to HV

Vacuum combines nearly perfect isolating and interrupting characteristics: it has an excellent dielectric withstand and enables a very fast re-establishment of its characteristics after current extinction. “However, raising vacuum technology from medium voltage to high voltage applications is not that simple,” says Dr Lutz Drews, R&D Manager at Alstom Grid. “For several reasons linked to the physics of vacuum and the nonlinear relationship between the inter-contact distance and the dielectric withstand, vacuum technology has only been applicable so far to distribution voltage levels not higher than 52 kV.” Some “vacuum” developments do exist for high voltage levels (i.e. 72 kV or higher), but they mainly address only a few niche markets – the industrial sector in Japan for example – and such circuit breakers commonly suffer some disadvantages: they are not truly 100 % $SF_6$-free (still using $SF_6$ for the dielectric insulation), they are mostly dedicated to “dead-tank” circuit breakers (whereas the world market is mainly “live tank”(1)), and they are not fully compatible with modern substation layouts. “Our objective was to design a 100 % $SF_6$ -free high voltage circuit breaker suitable for the whole world market and easily interchangeable with

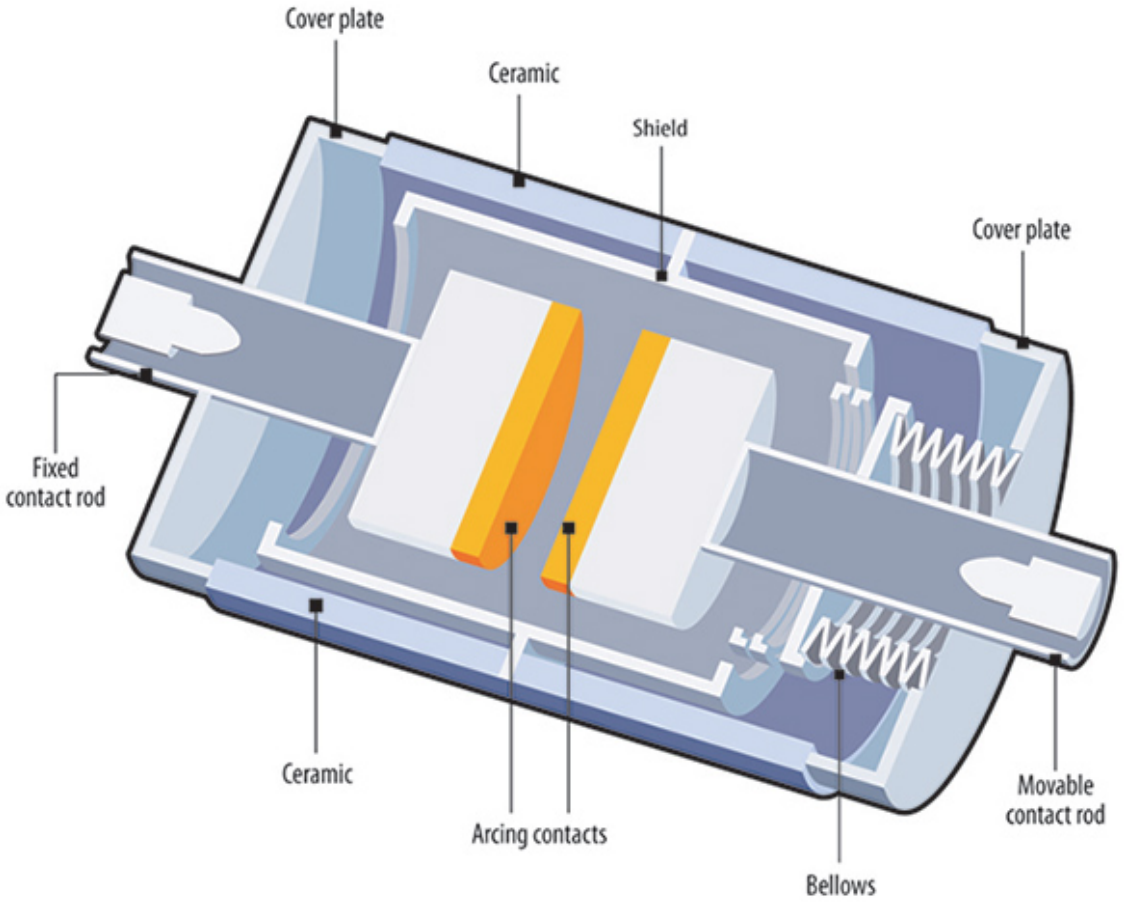
existing breakers; it would use vacuum as the interrupting technology and dry air for insulation between the terminals," explains Drews. The project led to the design and construction of the VL109 circuit breaker as a vacuum-type alternative to Alstom's $SF_6$-type GL309 model, with ratings of 72.5 kV/31.5 kA/2,000 A.

Several hurdles had to be overcome to get there. Compared with existing vacuum interrupters in the medium voltage range, the interruption at high voltage required an increased contact gap and a contact configuration providing an axial magnetic field. Furthermore, intensive investigations into contact materials were necessary to pass low current switching tests (e.g. for capacitive currents), and dielectric optimization was necessary to be able to use dry air for the insulation between the terminals and to achieve similar dimensions to the GL309-type circuit breaker. To respect the modified mechanical energy balance of the circuit breaker system itself and the lower required stroke of the vacuum interrupter, an optimisation of the mechanical chain was carried out, making it possible to keep Alstom's established FK-type spring-operated mechanism.

*« It uses vacuum as the interrupting technology and dry air for insulation. »*

At the same time, different configurations were also investigated: 2 vacuum interrupters in series, or 1 vacuum interrupter.
“We decided to choose the 1 vacuum chamber solution, because it enables us to stick with the current ‘candlestick’ design so that it can be fully interchangeable with existing 72 kV $SF_6$ circuit breakers; additionally, this solution does not require grading capacitors and it allows for higher mechanical reliability.”

(1) Circuit breakers are “live tank” when the enclosure of the interrupting unit is at line potential, or “dead tank” when the enclosure is at earth potential.




Vacuum interrupter layout.

Tests were performed for current breaking and switching at the KEMA high voltage laboratory in Arnhem (Netherlands) and CERDA in Villeurbanne (France). For mechanical lifetime, dielectric and environmental performance, tests were done at the Alstom Grid laboratory in Kassel (Germany). The VL109 passed all tests successfully. “The next step is to test the VL109 on the network,” says Drews. The first pilot vacuum-type breaker was installed at the end of 2012 on the French network. A second pilot will follow in spring 2013 on the Transpower network in New Zealand. “These pilot applications will allow us to gain experience concerning the switchgear itself as well as the impact of the switchgear on the transmission networks; we can collect evidence that the technology is reliable for use in high voltage transmission networks.” Alstom has now initiated a programme to transfer this vacuum HV technology to dead-tank type circuit breakers and to gas-insulated switchgear, as well as to extend the technology to higher voltage ranges.

**A new generation of HV circuit breakers: environmentally friendly, sustainable, fully interchangeable**

Curbing the greenhouse effect is a major objective, but also a challenge for Alstom, as the Kyoto Protocol compels manufacturers and users to reduce the amount of $SF_6$ in equipment and to reduce gas losses in service. Alstom’s new VL109 HV circuit breaker goes much further than the regulatory view since it does not contain any greenhouse gas at all. Using vacuum as the interrupting technology and dry air for insulation between the terminals, the product has a global warming potential of zero. Moreover, the vacuum interrupter is highly recyclable as mainly metals (steel, aluminium and copper) and ceramic are

used. An environmental and life-cycle analysis has shown that the vacuum technology-based VL109, compared to its $SF_6$ equivalent, has a climate change impact 24 % lower but with a higher electrical and mechanical lifetime and reliability. Last but not least, the VL109 is fully interchangeable with existing $SF_6$ circuit breakers.

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