Breaking to the front

Technological innovation in vacuum interrupters

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Life without electrical energy is hard to imagine. Throughout the industrial world, almost all aspects of life depend on the availability of a safe and reliable electricity supply. In the developing world too, more and more people are being connected to the electrical network.

A safe electrical supply would not be possible without the ability to switch the current on and off. Such functionality is vital for fault interruption, eg, due to short-circuits. Vacuum interrupters (VI) are a widespread technology at distribution level (10–40 kV).

The story of ABB's VIs is a success. In recent years production has grown exponentially, with ABB becoming the largest worldwide manufacturer in 2004. ABB's VI design is the most compact and shows an example of market leadership through technology leadership!

The worldwide electrical network is divided into different voltage levels. Voltages of up to 800 kV are utilized to achieve lower transmission losses over long distances. In regional distribution, voltages in the range of 10–40 kV are common. Low voltage (< 1 kV) is used in private households and low voltage industrial applications.

Different technologies have been developed in recent decades for interrupting current and voltage in the network. When an electrical current is interrupted, the formation of an arc between the contacts is unavoidable, no matter which medium fills the gap. The principle methods of extinguishing such an arc and safely isolating the two contacts can vary. Different media such as gases, liquids and additional ablation of solids have been utilized to extinguish circuit breaker arcs. These include air, SF_6, oil, and even purified water (for very limited applications in the past).

The development of the synthetic SF_6 gas introduced a very efficient arc-quenching medium. It has been applied to the whole voltage range of the transmission and distribution systems. In addition, SF_6 was, and partly still is used in non-electric applications such as sport shoes, scuba diving and medical applications.

The first industrially manufactured vacuum interrupters came onto the market in the 1960s. The development started in the US and Japan. During the following decades it was proven that vacuum is a very efficient medium for arc interruption, especially at distribution level (10–40 kV). Today, commercially available vacuum interrupters mainly cover rated voltages in this range, with short circuit currents of up to 80 kA. For lower ratings air is still the most economic solution, whereas for higher ratings SF_6 is more suitable.

Semiconductor based circuit breaker technology is feasible and has been demonstrated in a case study by ABB on a pilot installation at a customer site. Such solutions are still too expensive to compete with vacuum circuit breakers.

The ABB success story

ABB started to manufacture vacuum interrupters (VIs) in the early 1980s. The annual volume rose to about 30,000 units in the mid 1990s. During the past 10 years, enormous development has taken place with ABB dramatically stepping up its R&D activity. Driven by the R&D lead centre for vacuum interrupters in Ratingen, Germany together with ABB's Swiss Corporate Research Center, experimental set-ups, modeling and simulation

tools have been established, making ABB the technological leader in this field. With its detailed design know-how and sophisticated simulation tools, ABB today manufactures the world's most compact VIs. Optimized compactness and simplification are the ingredients for excellent reliability and robustness.

In addition, collaboration with universities in Germany and Russia have led to joint research activities and specialist recruitment.

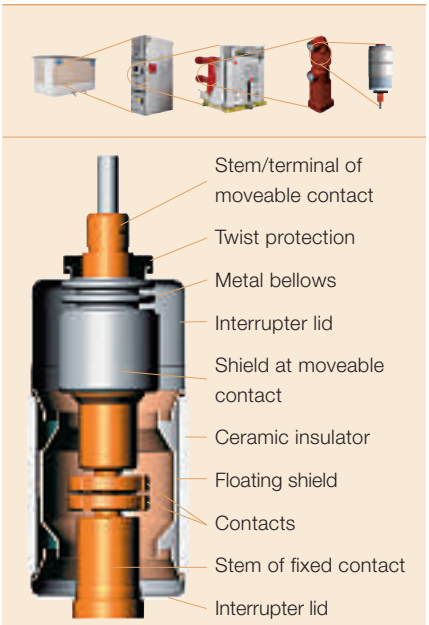
The annual production of ABB VIs has increased exponentially. A volume of more than 220,000 units in 2004 has made ABB the worldwide leader in VI manufacturing.

What happens when a vacuum interrupter operates?

1 shows a typical ABB vacuum interrupter. It consists of two copper-chrome contacts, one fixed and the other movable. The contacts are located inside a vessel that is evacuated to a pressure below 10^{-5} Pa. The vessel consists of a ceramic insulator, metal bellows for the movable contact, and a shield between the ceramic and the arcing region.

As soon as the contacts of a VI are separated, an arcing process starts. This arc is sustained by the external supply of energy until the next current zero. It is a metal vapor arc fed by so-called cathode spots from the contact material of the interrupter. By means of special contact geometry, the burning of the arc is prevented from concentrating in one place. ABB VIs mainly use spiral shaped contacts, generating a radial magnetic field (RMF) 2. This results in a rotary movement of the arc on the contact surface at a speed of a few hundred meters per second. This velocity reduces the erosion of the contact surface, thus extending the lifetime of the interrupter. As the current approches zero, the production of new plasma slows down. In a well-designed interrupter, no new plasma is produced at current zero. The remaining ions and electrons recombine quickly and condensate on the contacts and shield. The gap between the electrodes has to become insulating as soon as possible to prevent a re-ignition of the arc. During this time, the excellent dielectric strength of the vacuum helps recover the arcing path much faster than in any gas breaker. With a contact distance of just one centimeter, a withstand voltage of more than 150 kV can be achieved within microseconds. Unfortunately the dielectric withstand strength of a vacuum is not linear with electrode distance. This is the reason VIs are mainly used at distribution levels and only rarely for higher voltages.

1 Cut-away view of a vacuum interrupter.



A core platform element

ABB offers a wide range of interrupters. These are a basic element, which combined with other platform technologies, such as the epoxy embedding technology, form a modular "functional-block" system.

The "VG"-series for circuit breaker and recloser spans applications from 12 kV to 36 kV and is designed for maximal nominal currents of up to 3150A and maximum short circuit current levels of 63 kA (at 12 kV).

The "VS"-series is designed for contactor and switch-disconnector applications. Ratings range from 3.3 kV to 24 kV, and the technology is designed for up to 1,000,000 operations. These two VI lines form the core platforms for a number of applications.

One such application is the "embedded pole" [2] – (epoxy) platform. As a VI is maintenance free, it can be embedded in epoxy 3 to protect it from environmental influences.

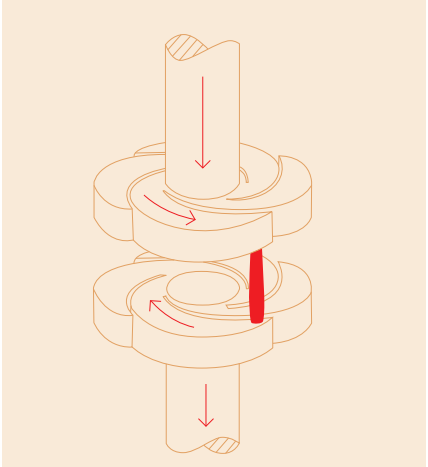
With its detailed design know-how and sophisticated simulation tools, ABB today manufactures the world's most compact Vaccum interrupters.

Vacuum interrupters and embedded poles have as few movable and fixed connection elements as possible, eliminating maintenance over the entire lifetime and leading to very compact and robust designs. The main advantages of embedded poles are: high dielectric strength without any further external precaution, applications in a wide range of climatic conditions and optimum protection of the VI from dust and moisture.

Another application is the "embedded outdoor pole", which is based on a special epoxy platform with water repellent surface features.

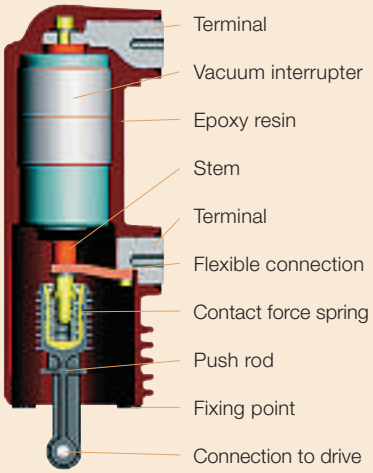
This hydrophopic epoxy platform has outstanding material properties. In climatic conditions down to –60 °C, where other materials would start cracking, this type of epoxy exhibits no deterioration. However, the pri-

2 Radial magnetic field contacts with spiral shape. The red arrows indicate the current flow.



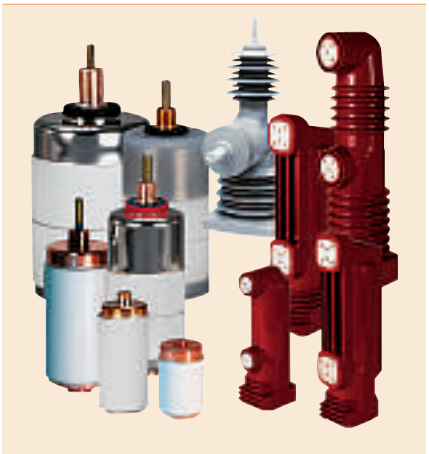
mary goal in pursuing this platform technology was not primarily low temperature behavior but long-term outdoor behavior. The new recloser was tested at KIPS Test Lab (ESCOM) in Cape Town, South Africa and easily passed the one year harsh environmental conditions test. Some devices from different competitors using porcelain or ordinary epoxy could hardly pass the half year hurdle.

3 Cross-section of an embedded pole with VI for 12 kV.



4 ABB VD4 Circuit breaker.

5 Vacuum interrupter, embededded poles and outdoor recloser.



Vacuum interrupters, whether embedded or naked are the core switching element for ABB medium voltage circuit breakers and are operated by either spring or magnetic drives.

This platform technology is also used in other applications such as outdoor instrument transformers.

In 2003 and 2004 ABB launched two poles for reclosers, one for 15–27 kV and one for 38 kV. These poles also contain small current transformers located in the horizontal terminal. It is an example of flexible embedding technology, as interruption and measurement can be combined into one common product.

Vacuum interrupters, whether embedded or naked are the core switching element for ABB medium voltage (MV) circuit breakers. They are operated either by spring or magnetic drives. ABB offers the VD4 breaker series 4 with embedded or assembled poles and a spring drive to cover more or less the complete range of primary and secondary applications. Magnetic drive technology is offered at 12 kV for up to 50 kA short-circuit current and at 24 kV for up to 25 kA.

A completely new innovative concept was shown at different fairs, introducing integrated sensing and control to the medium voltage circuit breaker landscape.

ABB also offers a smaller and lighter circuit breaker called Vmax. It covers ratings up to 17 kV/25 kA and consists of either a naked or silicone embedded vacuum interrupter and a spring drive, customized for low duty applications.

No matter what kind of insulation technology is used, the main requirement is to interrupt the current in the network. The platform technology of ABB´s vacuum interrupter series is the basis for all these MV products 5.

The worldwide market trend in many parts of our business is towards vacuum technology and ABB is in an excellent market position to support this need thanks to their technological leadership.

References

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