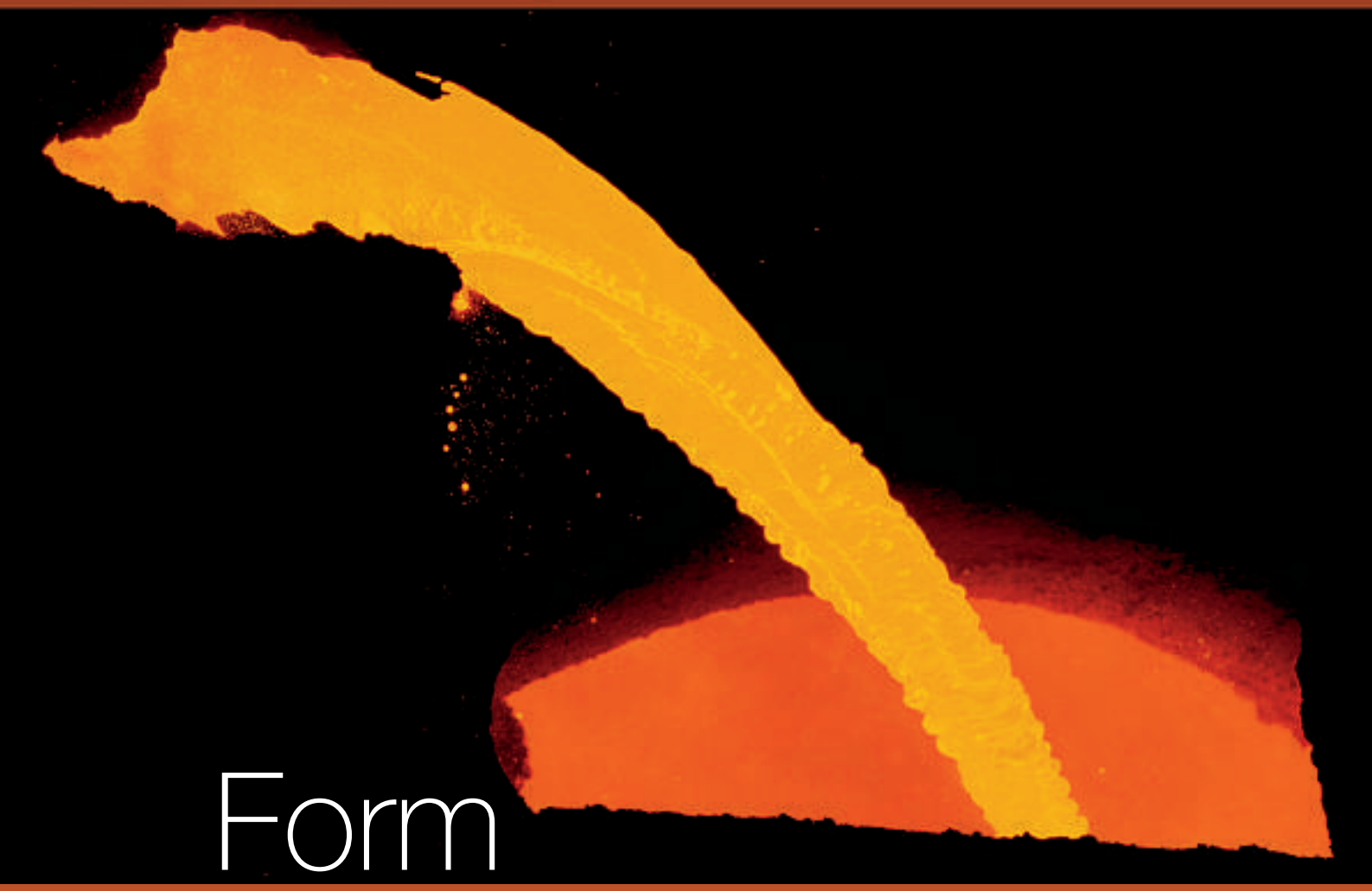


Form and function

Embedding vacuum interrupters in epoxy boosts reliability for both indoor and outdoor applications

Edgar Dullni

Hot or cold, stormy or calm, indoors or out, vacuum interrupters must withstand what the environment throws at them. Dirt and dust particles accumulating on the outside are also a hazard as these reduce the voltage withstand.

Electrical short circuit currents and voltage surges, and mechanical shocks and vibrations add to the "abuse" these devices must endure.

How can manufacturers meet customers requirements of making a device resilient to degradation and malfunction under such extreme conditions?

ABB has responded to this by using an innovative technique of embedding the interrupter in epoxy resin to form a complete pole. These embedded poles, maintenance-free throughout their service life, are modular in construction, and compact and robust in design. The embedding technique also permits detection and measurement devices to be integrated, and simplifies handling and installation. Never before has a vacuum interrupter been so comprehensively protected as in an embedded pole.

The need for circuit breakers across the world is rising due to the increasing demand for electricity. Even though customers consider price to be a central factor for selecting a product, life-cycle costs are becoming equally, if not more important. When it comes to breaker selection, distinctive criteria include:

- Reliability of electricity transport and current interruption.
- No impact from environmental factors.
- No maintenance required until end of product life.
- Ease-of-use achieved by ultimately using in-built intelligence.

In the last three decades, vacuum circuit-breakers have more than proven their reliability. The current generation of ABB interrupters covers network voltages from 12 to 38 kV, short-circuit currents up to 63 kA and rated currents up to 4000 A [1]. In late 2004, the existing VG-interrupter family was extended to 31.5 kA at 40.5 kV. A smaller interrupter, VGE5, was launched for 16 kA at 12kV.

Environmental conditions have a considerable impact on circuit-breakers. Dust, dirt, chemicals and moisture accumulating on the outer surface reduce the voltage withstand. In outdoor applications, rain and ice have a similar effect. Temperature cycles and external shocks and vibrations make high demands on mechanical stability. Lightning and switching transients cause over-voltage stressing insulation.

ABB has addressed these issues by embedding many of its maintenance-free interrupters in epoxy [1]. Embedding a vacuum interrupter in epoxy forms a complete pole, and such a device is more commonly known as an embedded pole.

Vacuum interrupters and embedded poles have as few movable or fixed connection elements as possible, eliminating maintenance over the entire life cycle.

Embedding vacuum interrupters in epoxy not only protects them from external damage but also promises long life and high reliability.

Spring-operated mechanisms have more moving parts, and maintenance is recommended after 10,000 operations. For very high switching frequencies, ABB offers a permanent magnetic actuator for indoor [1] as well as for outdoor applications, extending the number of operations between maintenance up to 100,000 – making maintenance practically obsolete.

A vacuum breaker is normally part of a switching and protection environment that is equipped with current and voltage measurement, detection and recording, and an electronic evaluation unit.

Complete integration within the breaker is mandatory for outdoor applications and also advantageous for indoor breakers. In 2004, ABB launched the eVM1 breaker, which for the first time, integrated measurement, protection and control functions within a single-device indoor circuit breaker.

Embedded interrupter poles

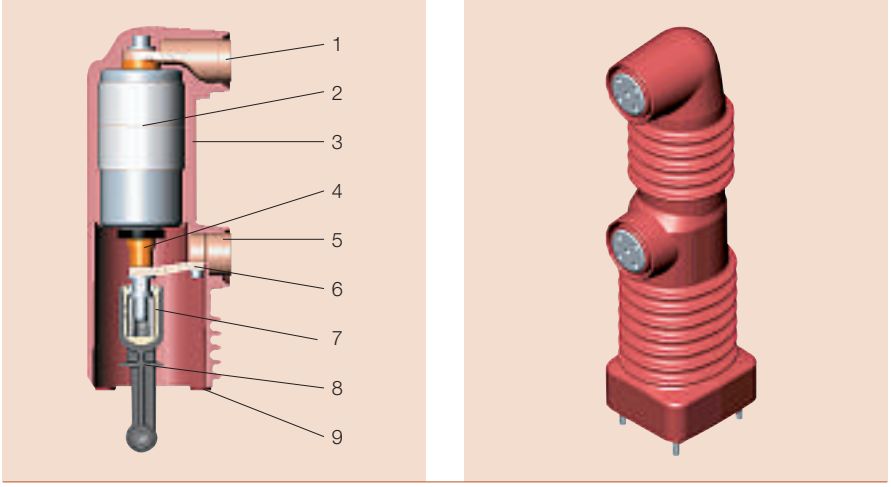
The conduction and interruption of short-circuit currents places great demands on vacuum interrupters. But their robust construction ensures fault-free and maintenance-free operation for a service life of decades.

Embedding these in epoxy not only protects them from external damage but also promises long life and high reliability. Epoxy resin as a material more than meets the requirements of mechanical and dielectric strength.

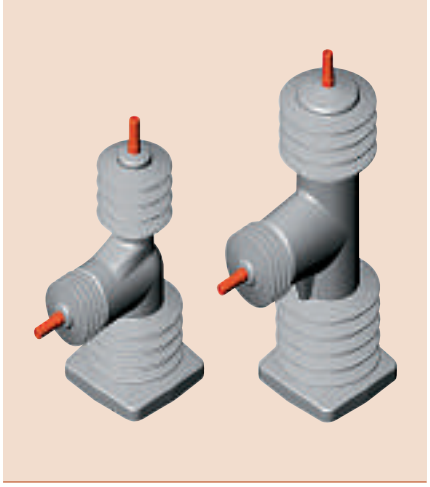
The embedded poles are manufactured at ABB using an Automatic Pressure Gelation (APG) process. The epoxy resin is fed into the preheated mould containing a vacuum interrupter. During gelation, the epoxy resin is subjected to high pressure and throughout the entire moulding process, the vacuum interrupter is held by its terminals. Once the epoxy material has set, the interrupter is held in position with no further need for mounting or fixing. The design takes into account the different expansion coefficients of epoxy and inserts. All poles are tested under rapid temperature cycles (+50° to –60°C) demonstrating their applicability under severe climatic conditions.

Besides all relevant IEC standards, the new embedded pole for 36 to 40.5 kV also fulfils the rather severe Chinese

1 Cross-section of embedded pole with vacuum interrupter for 12 kV and latest embedded pole for 36 kV (1) upper terminal, (2) vacuum interrupter, (3) epoxy resin, (4) movable stem, (5) lower terminal, (6) flexible connection, (7) contact springs, (8) push rod, (9) mounting inserts.



2 Embedded outdoor poles for 15 – 27 kV / 1000 A / 12 kA (left) and 38 kV / 1000 A / 16 kA (right).



GB standard prescribing an AC testing voltage of 95 kV and a lightning impulse voltage of 185 kV even across the open interrupter. To be sure these standards are met, the internal shields of the interrupter were fit to purpose.

The external insulation of the interrupter is achieved by its complete sealing in epoxy. Additional outside epoxy sheds (see 1b) between the two terminals and from the lower terminal to ground increase the external creepage length and provide better resilience to condensation and pollution.

High creepage length is especially important for outdoor applications. The sheds have to be much larger and of a special shape in order to achieve appropriate behaviour under pollution.

The cross section of an embedded pole with a vacuum interrupter for 12 kV is shown in 1a. The current is transmitted through the upper terminal, the vacuum interrupter, a conductor link carrying out the mechanical stroke and the lower terminal. The insulating push rod which is firmly attached to the moving lower terminal of the interrupter establishes the connection to the circuit breaker's operating mechanism. Within the push rod, there are contact pressure springs to ensure a defined contact pressure.

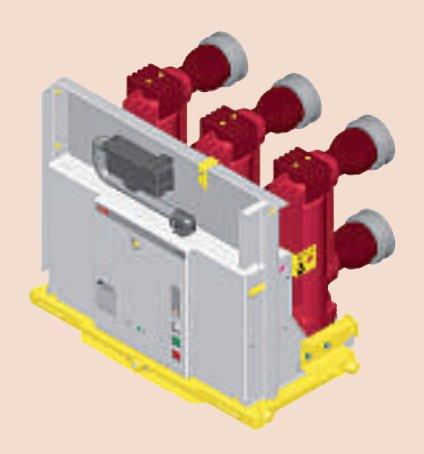
In 2003 and 2004, ABB launched two outdoor embedded poles 2, one for 15–27 kV and one for 38 kV providing creepage lengths of at least 35 mm/kV that can easily cope with pollution level IV according to IEC60815. These poles also contain a small current transformer located on the horizontal terminal. This again makes the embedding technique advantageous, since it implements interruption and measurement all in one.

Application to circuit breakers and reclosers

The embedded pole family is universal in its application. For example, a pole can be easily adapted to circuit breakers, and switchgear operators can use them in all forms of climatic conditions. They are handled as one piece and are therefore shipped ready for use, thus avoiding the need for any special adaptations.

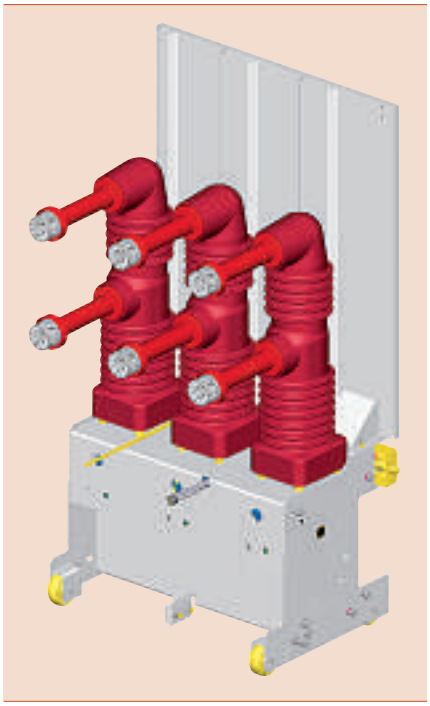
3 shows an indoor circuit-breaker, type VM1 which uses a magnetically operated mechanism. This type is especially suited for frequent operations. It is available for the 12 to 24 kV range and for short-circuit currents up to 50 kA, and it can be inserted in an air-insulated switchgear.

3 VM1 indoor circuit-breaker for 12 kV and 40 kA with embedded poles.



The 36 kV application, 4, needs a mechanism providing a larger contact stroke and larger external dimensions than at 12 and 24 kV. In this case a spring-operated mechanism is used. It is available as a "movable truck" or as a fixed version. The contours of the terminals have been given special attention to facilitate insulation of add-on connections.

4 VD4 indoor circuit-breaker for 36 kV and 31.5 kA with the new embedded pole P6.



The last application example is the so-called outdoor recloser 5. These devices are used mostly on ANSI markets and can open and close within seconds to clear a faulty line. For this purpose a magnetic actuator is used, which is able to trip up to four times within 5 seconds. The operating energy is stored in a unit consisting of a capacitor and a battery. The switching sequence is provided by an electronic control and protection device working together with the current transformers integrated into the poles.

5 OVR outdoor recloser for 27 kV and 12 kA with embedded pole.

Summary

A complete family of embedded indoor and outdoor poles with vacuum interrupters constitute a suitable platform for many applications for indoor circuit-breakers and outdoor switchgears. They assure high resilience against environmental influences and need no maintenance. With a recently developed pole, the family has been extended into the 36 kV voltage range for indoor switchgear. For outdoor poles, embedding has an even higher impact because measurement coils can be integrated into the pole.

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