

New vacuum interrupters for contactors and switches

The advantages of vacuum technology, as demonstrated for example by vacuum circuit-breakers, persuaded ABB Calor Emag Mittelspannung GmbH of Germany to develop a range of vacuum interrupters for contactors and switches rated up to 12 kV and 36 kV, respectively. Switching devices equipped with the new interrupters are extremely compact and robust, and easily satisfy all the electrical and mechanical requirements specified in the pertinent IEC standards.

ABB Calor Emag Mittelspannung GmbH, Germany, has been developing and manufacturing vacuum interrupters for circuit-breakers since the early 1980s [1]. At the company's R&D center in Ratingen, engineers use state-of-the-art tools and powerful computer software, eg for the electrical and magnetic field calculations, to optimize the design and functionality of the interrupters.

Among the most recent results of this work are new contact materials and contact systems based on both radial magnetic field (RMF) and axial magnetic field (AMF) principles [1,2]. These new systems and materials easily satisfy the requirements that have to be met by medium-voltage circuit-breakers:

- Rated voltages up to 52 kV
- Rated short-circuit breaking currents up to 63 kA/80 kA
- Rated currents up to 5000 A

Circuit-breakers equipped with vacuum interrupters have been commercially available for almost two decades, during which time they have proved their worth in a wide

range of applications. No other kind of circuit-breaker is as versatile or reliable, requires less maintenance or is environmentally kinder. All of these advantages of vacuum technology can be made available to contactors and switches by modifying it accordingly. ABB Calor Emag Mittelspannung has therefore developed a new family of vacuum interrupters, designated VS, for use in contactors and switches. Although these two applications do not make the same high demands on the rated short-circuit breaking current as circuit-breakers, several special requirements have to be satisfied, eg in the case of vacuum contactors a lifetime of at least 1 million mechanical switching cycles.

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Requirements to be met by vacuum interrupters

Contactors

The pertinent standard for contactors with rated voltages of more than 1 kV is IEC 60470 [3]. This standard defines the requirements the contactor has to satisfy as well as the so-called 'utilization categories', AC-1, AC-2, AC-3 and AC-4. The higher the AC number, the higher the required switching capacity of the contactor.

Since all of the VS vacuum interrupters for contactors satisfy the maximum requirements, only the highest utilization category, AC-4, is looked at here. This describes a cage induction motor application involving starting, plugging, reversing and inching. *Table 1* gives the applicable values for the rated making capacity and rated breaking capacity, both of which depend on the specified rated current.

The values in *Table 1* take account of the fact that contactors are often used to switch motors on and off. Since the switching frequency is therefore much higher than with circuit-breakers, contactors and their vacuum interrupters have to exhibit much longer mechanical and electrical lifetimes. As rule, the minimum required number of switching cycles over the lifetime of the contactor is 1 million. For special applications, the same number of switching cycles is required at rated current.

Contactors are also used to switch small capacitor banks in accordance with IEC 60056 [4]. For this application, the vacuum interrupter must be capable of interrupting without restriking, since restriking causes overvoltages that could destroy the connected apparatus.

Switch-disconnectors

IEC also defines the main requirements for switches and switch-disconnectors: IEC 60265-1 [5] deals with the switchgear



Some of the vacuum interrupters manufactured by ABB Calor Emag Mittelspannung GmbH

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and IEC 60420 [6] with the interactions taking place in switch-fuse combinations. Unlike the interrupters used in contactors, an interrupter in a switch-disconnector only has to be able to interrupt currents of the order of magnitude of the rated current (IEC 60265-1). During testing of the so-called transfer current (IEC 60420) a somewhat higher current could flow, depending on the current rating of the fuse. However, as a rule all the switching operations are handled reliably by the vacuum interrupter and make no special demands on its design.

It is considerably more difficult to verify fault throwing (ie, making on a short-circuit). IEC requires the switch, and therefore usually the vacuum interrupter, to be capable of making on a full short-circuit current up to five times without the contacts welding together. The maximum mechanical and electrical lifetimes lie in the region of 10,000

switching cycles, a figure which is not usually a problem for a vacuum interrupter.

Switches must also be capable of disconnecting capacitor banks without restriking. Capacitive interruption, for which high dielectric strength is essential, is also required for frequent disconnections of overhead lines and cables under no-load or low-load conditions.

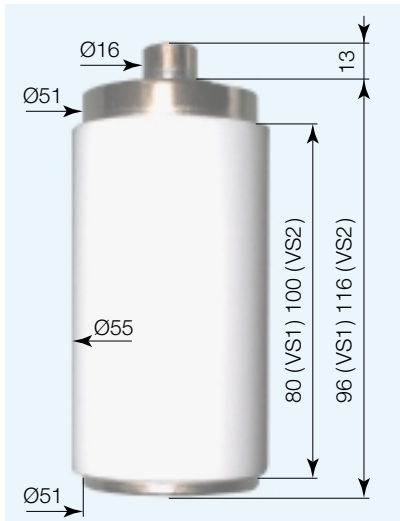
The highest demands are made on the dielectric strength when the rated

cable-charging breaking current has to be interrupted under earth-fault conditions (IEC 60265-1). In this case, the peak transient recovery voltage (eg, 68.8 kV for a rated voltage of 24 kV) is higher than for an interruption without earth fault by a factor of about 1.4. This makes enormous demands on the dielectric strength of vacuum interrupters.

Summing up, it can be said that while contactors and switches make similar de-

Table 1:
Rated making capacity and maximum breaking capacity given in IEC 60470 (utilization category AC-4)

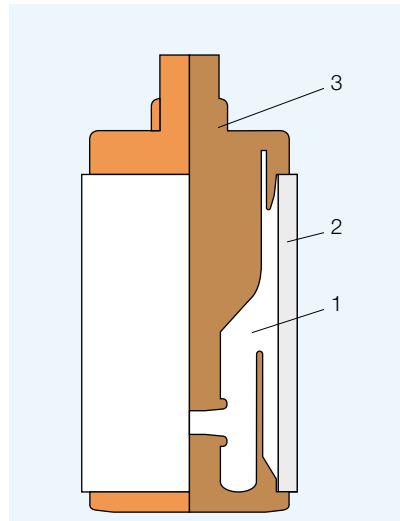
	I/I_e	U/U_e	$\cos \varphi$	No of tests
Rated making capacity	8	1.1	0.35	100
Max rated breaking capacity	10	1.1	0.35	25
I_e Rated current		U_e Rated voltage		



Vacuum interrupter VS1/VS2 for use in contactors

VS1 interrupter rated 7.2 kV, 400 A
VS2 interrupter rated 12 kV, 400 A

Dimensions in mm



Sectional view of the VS vacuum interrupter

- 1 Vacuum ($\leq 10E-7$ mbar)
- 2 Al_2O_3 ceramic
- 3 OFHC copper



All VS vacuum interrupters feature a guide flange for the movable stem and an anti-torsion device to prevent the bellows from twisting.

mands on the vacuum interrupters, considerable differences exist between them. The challenge for the development engineers was therefore to design an interrupter that was economically priced and compact and which, in spite of the dissimilarities, could be used for both applications.

The new VS series of interrupters

VS1/VS2 interrupters for contactors

Vacuum interrupters designed for a rated voltage of 7.2 kV and rated current of 400 A satisfy most of the demands made on medium-voltage contactors. The smallest of the new interrupters, the VS1 **2**, was therefore dimensioned with these ratings. For the 12-kV market, ABB Calor Emag Mittelspannung developed the VS2, which also has a rated current of 400 A. The VS2 has a longer ceramic body **2** than the VS1 to increase the insulation in air. This is necessary because of the in-

creased rated lightning impulse withstand voltage and rated short-duration power-frequency withstand voltage that result from the higher rated voltage.

3 shows a sectional view of the VS1 (7.2 kV, 400 A). As with all vacuum interrupters from ABB Calor Emag Mittelspannung, the insulator material is high-purity Al_2O_3 ceramic. With the exception of the contacts, the metallic parts are made of oxygen-free high conductivity (OFHC) copper. The parts with complex shapes are produced by means of hot press forging.

The contacts of the VS1 and VS2 interrupters for contactors are made of WCAg instead of the more commonly used CuCr. The hard-metal component, tungsten carbide (WC), makes the contacts resistant to erosion caused by arcing. As a result, contacts have an electrical lifetime of several hundred thousand switching cycles at rated current. Also, with WCAg the chopping current is in the region of 0.5 A, compared with 3 to 5 A for CuCr, which is used widely in circuit-breakers. This helps

considerably to reduce possible overvoltages caused by the current in the inductance before chopping being re-directed into the parallel capacitance.

A new bellows has also been developed with a mechanical lifetime of at least 1 million switching cycles. VS interrupters have a guide flange through which the movable stem passes and which gives it a certain axial freedom in relation to the cover, plus an anti-torsion device to protect the bellows from twisting **4**. A special feature is the use of copper for both the cover and the conductor. To stop these two parts from being cold-welded together during switching or the insertion of the interrupter, the latter is hard-plated with chromium. Wear on parts is therefore only minimal, allowing up to 2 million switching operations. The wing-like protrusions on the conductor engage in the cover to prevent the bellows from twisting during assembly, etc.

The successful development of new, compact vacuum interrupters depends to a large extent on correct calculation of the electrical field. **5** shows the

electrical potential distribution and the electrical field strength in the VS1 for an applied voltage of 60 kV. This value is specified in IEC 60694 [7] as the peak value of the rated lightning impulse withstand voltage under more severe conditions. In spite of being extremely compact, the VS1 and VS2 interrupters easily satisfy the dielectric requirements imposed by the rated short-duration power-frequency withstand voltage and rated lightning impulse withstand voltage. It goes without saying that this also applies to the VS vacuum interrupters designed for use in switches, for which the test voltages are even higher due to the higher rated voltage.

The impressive way in which the VS1 handles a three-phase interruption as per IEC 60470 (utilization category AC-4) can be seen in **6**. The oscillograms show the interruption of a short-circuit current of 4 kA (recovery voltage 7.9 kV). Whereas IEC 60470, AC-4, only requires 3.2 kA, the rated interruption current of the VS1 and VS2 is 4 kA. Both VS1 (7.2 kV) and VS2 (12 kV) easily satisfy the requirements given in the standards for the different switching operations.

VS3/VS4 interrupters for switches

Two vacuum interrupters have been developed by ABB Calor Emag Mittelspannung for use in switches: VS3 with a rated voltage of 12 kV, and VS4 with 24/36 kV. Both classes have the same outside dimensions as the VS2 interrupter **2**. Since, due to its extremely compact design, the external insulating distance of the VS4 does not satisfy the dielectric requirements specified in IEC 60694, either the switch compartment in which the interrupter is mounted has to be filled with an insulating compound that forms a mould around it, or an insulating gas with a higher dielectric strength has to be used.

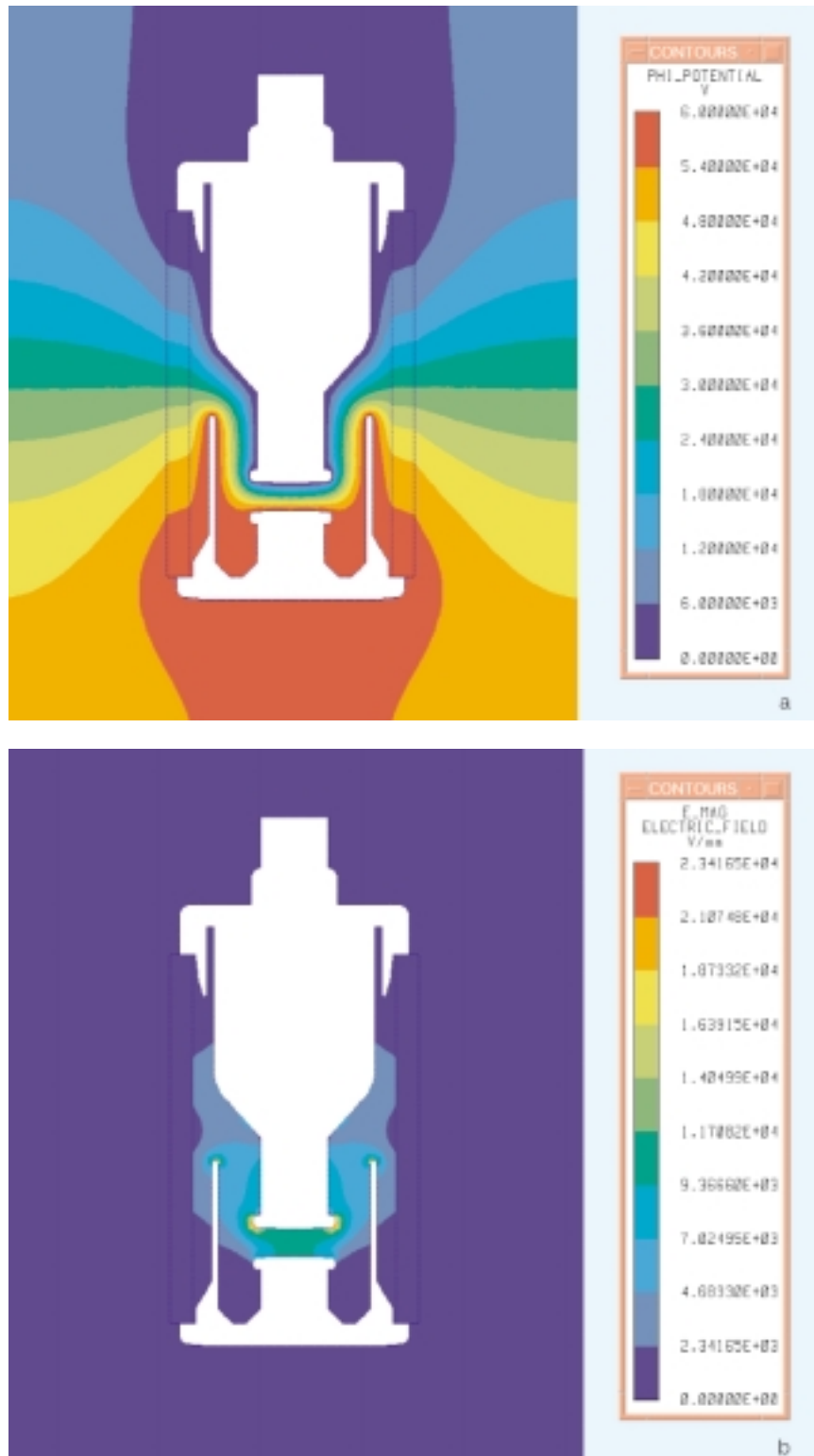
The additional cost of this is, however,

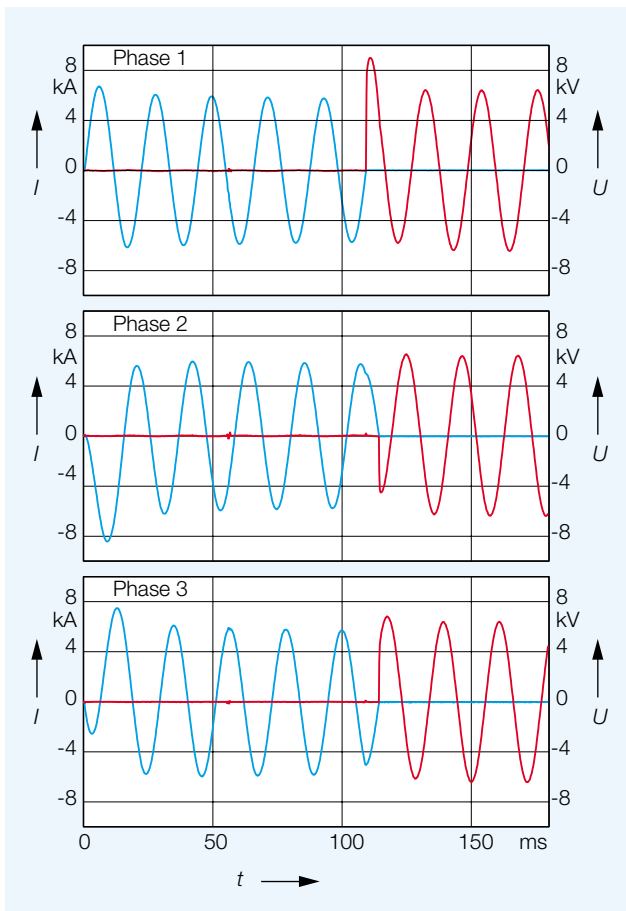
offset by two important advantages: due to the outstanding insulation properties of the vacuum, the internal structures can be

made more compact and the design more cost-effective. If the ceramic body of a vacuum interrupter had to be shaped to

Electrical potential distribution (a) and electrical field strength (b) in the VS1 interrupter for an applied voltage of 60 kV

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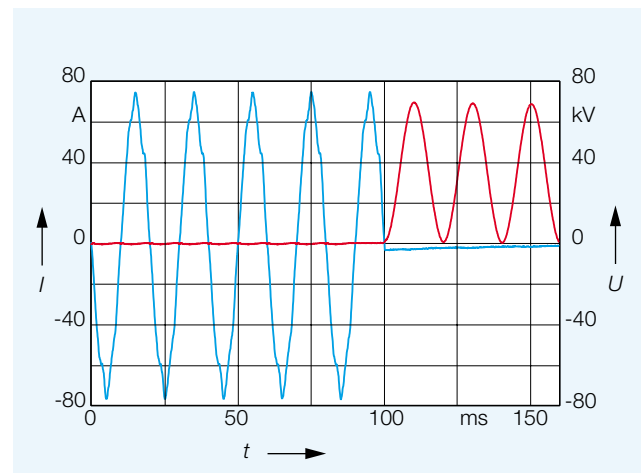


Oscillogram of a three-phase interruption of a 4-kA short-circuit current (recovery voltage: 7.9 kV), performed with a VS1 interrupter

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Oscillogram of a single-phase interruption of a rated cable-charging breaking current under earth-fault conditions, performed by a VS4 interrupter (rated voltage: 24 kV)

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achieve the same dielectric strength, the overall cost would be considerably higher.

For many of the applications with such switch interrupters the use of additional insulating moulding is anyway planned. The bellows used with VS3 and VS4 are the same as those used with the interrupters for contactors. Also the same are the guideways and anti-torsion devices. An oscillogram of a cable-charging breaking current being interrupted by a VS4 (rated voltage 24 kV) under earth-fault conditions (53 A) is shown in 7. Vacuum interrupters handle even interruptions of this kind without restriking.

With its VS family, ABB offers a series of vacuum interrupters that satisfy the IEC standards with ease and also meet demand for a uniform, compact and cost-effective design.

References

- [1] H. Fink, D. Gentsch, G. Pilsinger, W. Shang: Vakuumschaltkammern für zuverlässige Mittelspannungsschaltgeräte. *Elektrizitätswirtschaft* 96 (97) 14, 749–752.
- [2] H. Fink, D. Gentsch, M. Heimbach, G. Pilsinger, W. Shang: New developments in vacuum interrupters based on RMF and AMF technologies. 18th International Symposium on Discharges and Electrical Insulation in Vacuum, 1998, Eindhoven, Netherlands.
- [3] IEC 60470: High-voltage alternating current contactors, 1974.
- [4] IEC 60056: High-voltage alternating current circuit-breakers, 1987.
- [5] IEC 60265: High-voltage switches – Part 1: Switches for rated voltages above 1 kV and less than 52 kV, 1998.
- [6] IEC 60420: High-voltage alternating current switch-fuse combinations, 1990.

[7] IEC 60694: Common clauses for high-voltage switchgear and controlgear standards, 1996.

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