Integrated

eVM1 medium-voltage circuit-breaker combines interruption, measuring and protection capability

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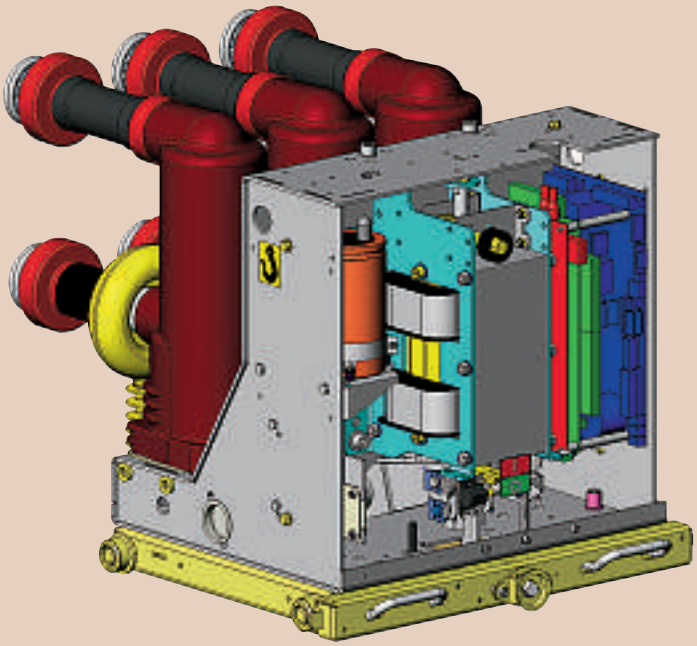


Medium-voltage switchgear, like all other power supply equipment, has to compete in the marketplace on the customers' terms. Topping the wish list are higher reliability, faster installation, longer intervals between maintenance and reduced lifecycle costs. To achieve these goals the switchgear has to be made less complex, for example by increasing standardization, yet at the same time more versatile. Innovative ABB technology has solved this dilemma by enabling all the functionality of outgoing feeders or medium-voltage motor applications to be combined in one intelligent integrated device – the eVM1 circuit-breaker.

Recent years have seen a strong trend toward more integration in equipment for medium-voltage distribution. Products featuring a higher degree of component standardization and increased overall versatility have come onto the market that improve reliability while also reducing the time and effort needed for installation and maintenance.

ABB is in the vanguard of this development. A recently launched series of medium-voltage circuit-breakers, named eVM1, was developed specifically to make more compact and reliable solutions possible in medium-voltage switchgear for primary distribution.

The new circuit-breakers combine innovative ABB technologies in the fields of mechanics, electronics and sensing. The result is a highly integrated intelligent device that adds measurement, protection and control capability to the primary power interruption technology.

Built on a proven platform

The circuit-breaker on which the new integrated eVM1 is based is ABB's medium-voltage 'VM1'. This magnetically actuated vacuum circuit-breaker was introduced to the market in 1998, and has demonstrated its excellent reliability and maintenance-free design in thousands of applications all over the world.

In the eVM1, Rogowski coil current sensors are mounted on the breaker's poles and protection and control functionality is included in an electronic device in the circuit-breaker housing. Digital communication to a station automation system is planned for the near future.

The fully integrated eVM1 offers some significant advantages over conventional MV breakers in the area of installation and operation:

- Preparation of the specification and ordering procedures is simplified, enabling faster delivery.
- The circuit-breaker is fully tested in the factory with most of the other

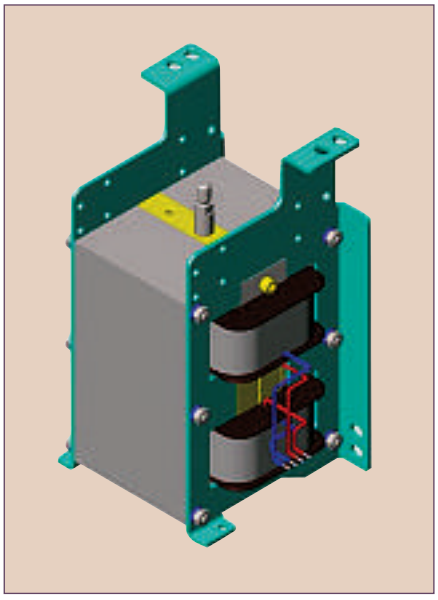
components of the switchgear panel also fitted.
- Panel wiring has been dramatically reduced, practically eliminating the risk of wiring errors and their consequences. Installation work on the substation is therefore completed sooner.
- Safety and operational reliability are improved.
- The complete system documentation is available from the beginning of a project.

The eVM1 is the first version of a new series of circuit-breakers. Available with current interruption ratings of 1250 A and 31.5 kA at 12 kV, it has built-in functionality for configuring various types of phase overcurrent, earth-fault overcurrent and motor protection schemes.

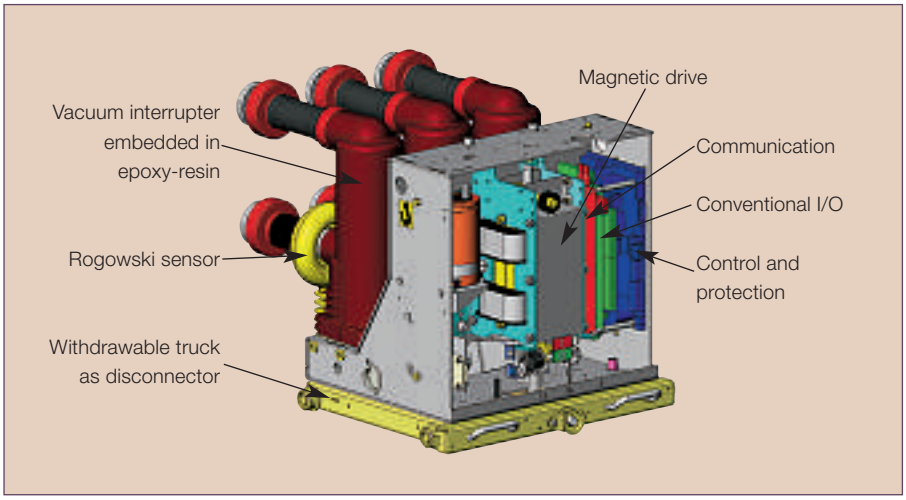
Components of the eVM1 breaker

Unlike conventional, spring-operated circuit-breakers, the VM1 and eVM1 have a very simple mechanical structure and require no maintenance. This is mainly because they have fewer parts, plus there are no parts that are subject to wear and need lubrication in order to function properly [1]. The risk of breaker failure is significantly lower as a result of this much simpler design 1.

2	The magnetic actuator used in the eVM1 can handle up to 100,000 CO operations over its lifetime.



1	Main components of the integrated eVM1 medium-voltage circuit-breaker



Robust magnetic actuator

A vacuum interrupter requires a low force for operation when the breaker is open and a high force when it is closed. Magnetic actuators, unlike spring-operated drives, have no difficulty in fulfilling this requirement.

The highest force is generated in the end position, where strong permanent magnets lock the circuit-breaker in position [2]. The advantage of using permanent magnets is that no electrical power is needed to hold the breaker in the open or the closed position. A major benefit of magnetic drives is their robust design. Up to 100,000 close-open (CO) operations are possible over a drive's lifetime 2.

Maintenance-free vacuum interrupters

Vacuum is a widely accepted interruption technology today, and for good reason: vacuum interrupters require no maintenance and they are sealed for life (30 years and more, with up to 30,000 CO operations possible).

ABB's continuing investment in vacuum technology has produced a vacuum interrupter family with very competitive dimensions 3. These vacuum interrupters form the 'core' of the new eVM1 series [3].

(More information on ABB vacuum interrupters can be found in an article beginning on page 22 of this issue of *ABB Review*.)

The advantage of embedded poles

Since the outer insulating surface of a vacuum interrupter is normally exposed to air or other gases, there is a significant risk of dirt, etc, building up on the ceramic envelope. The usual way to reduce this risk is to increase the length of the envelope, but this makes it even more difficult to achieve a compact design. For the eVM1, ABB therefore chose to embed the vacuum interrupter in epoxy resin, which can be shaped very easily. As a result, the ceramic envelope is much shorter and the interrupter is perfectly shielded from dust and moisture 4. Additional mounting and securing of the current-carrying parts is also unnecessary. Embedding the poles in this way has reduced the number of parts, short-

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ened assembly time and eliminated several possible failure modes.

Rogowski coils – compact current sensors

A key feature of the integrated breaker is its current sensors, which are based on Rogowski coils to reduce size and weight.

A Rogowski coil consists of a helical coil of wire with the lead from one end returning through the center of the coil to the other end, so that both terminals are at the same end of the coil. Because of its air core, the Rogowski coil has a low inductance and can respond to fast-changing currents. Such a coil has many advantages over an iron-core current

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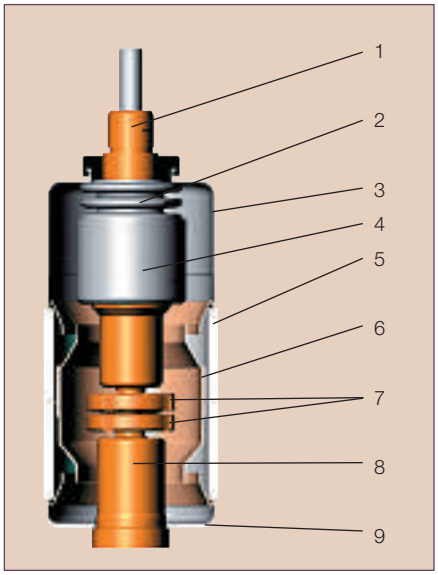
transformer (CT), which is the type most commonly used for current measurement in MV switchgear. First, since it has no iron core to saturate, the Rogowski coil exhibits very good linearity even when high currents are being measured. Next, it can be used for isolated current measurement and has a very wide bandwidth. Losses are also low, as the coil

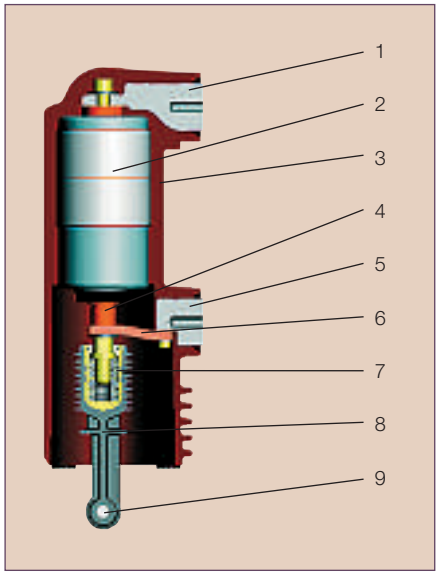
5 Conventional current transformer (left) and the much smaller Rogowski coil current sensor (right)

3 Compact vacuum interrupters are at the heart of the new eVM1 series.



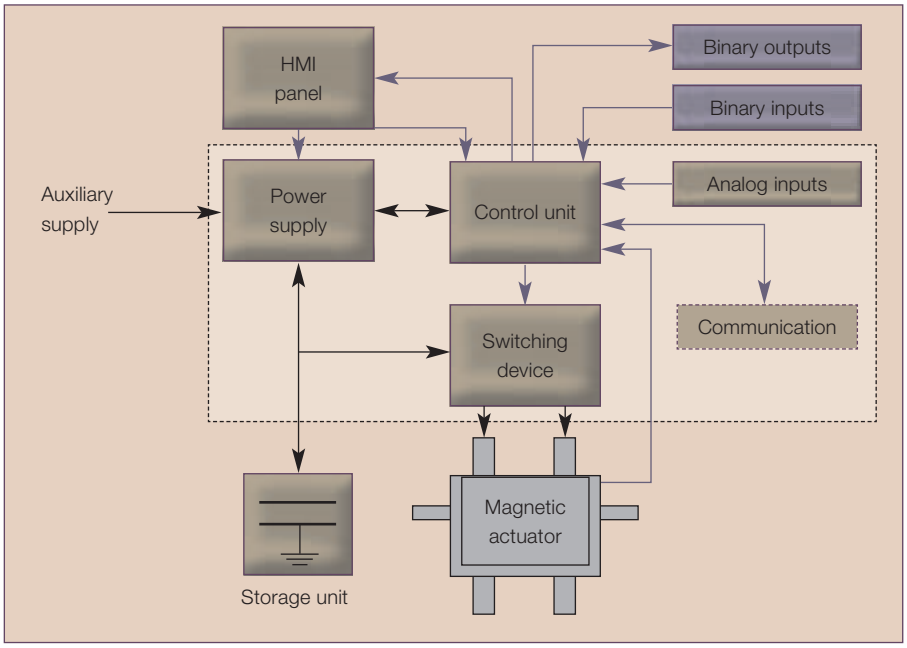
1 Stem/terminal
2 Metal bellows
3 Interrupter lid
4 Shield
5 Ceramic insulator
6 Shield
7 Contacts
8 Stem
9 Interrupter lid

4 Embedded poles shorten assembly time and eliminate possible failure modes.



1 Terminal
2 Vacuum interrupter
3 Epoxy resin
4 Stem
5 Terminal
6 Flexible connector
7 Contact spring
8 Push rod;
9 Connection to drive

6 Control electronics and information management architecture of the eVM1



makes no demands on the primary circuit. What is more, the small size 5 and low weight of the coil contribute to a very good life cycle assessment (LCA) result. Finally, safety is enhanced as there is no chance of the dangerous overvoltages that can occur in conventional CTs when the secondary is left open.

From most standpoints, the Rogowski coil is the ideal current sensor for applications in which DC measurement is not normally required. In fact, the only drawback is that the output is proportional to the time derivative of the current and therefore has to be integrated. This was a problem with the earlier analog integrators, which were not accurate enough. The problem is solved with eVM1 which, like modern protection relays, makes use of numerical integration.

As a result, the sensor's accuracy class is 1%. Temperature changes, assembly tolerances and cross-talk are all taken into consideration; a final calibration of the *complete* measurement chain, performed in a protected environment, ensures the highest accuracy possible.

As the Rogowski coil does not saturate, it can be used to measure currents ranging from a few amps to tens of kiloamperes. The maximum and minimum values are defined by the linear range of the eVM1 breaker's measuring module.

The coil's good linearity allows all applications to be covered with just one coil rating and enables high fault currents to be accurately measured. The Rogowski coil also exhibits excellent qualities with regard to phase angle accuracy and electro-magnetic compatibility (EMC).

Phase angle: High phase angle accuracy is very important for many protection algorithms. The problem with iron core CTs is that the phase shifts with the current, especially during under- or over-excitation. This is not a problem with Rogowski coils as the phase shift error is small and does not vary with current.

EMC: Due to the high sensitivity of the new current sensor (a few millivolts per ampere for 50 Hz signals), EMC was a key consideration at every stage of the design. Thanks to the high level of component integration, the eVM1 has some inherent advantages in this area – short cables and original specifications that effectively exclude mutual interference. Extensive testing has confirmed the immunity of the eVM1 to electro-magnetic disturbance.

Control electronics and information management

All of the described functionality is provided by three modules 6:

Main processing module with integrated power supply for the eVM1; it charges the capacitor storage unit required to operate the magnetic actuator and is also responsible for analog signal acquisition and the analog-to-digital conversion of the Rogowski coil signals. Through its control unit it oversees current measuring, protection, monitoring, signaling and system autodiagnosis. Information is exchanged with the binary I/O board and communication board. An insulated RS485 port for the configuration tool is embedded in the motherboard.

> The eVM1 shows just how simple an MV panel can be while still combining all the functionality required for the most common applications.

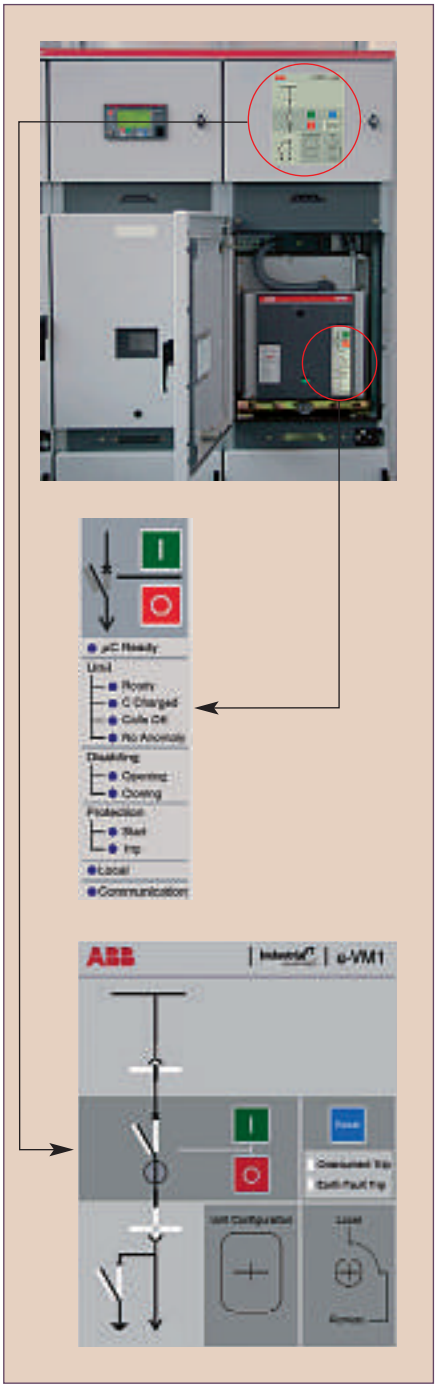
Binary I/O module, comprising 16 binary wide-range insulated inputs and 16 outputs with wide-range insulated relay contacts for conventional wiring.

Communication module (optional); implements the Modbus protocol for communication with a station automation system (SCADA). Implementation of further protocols is planned for the near future.

Operating the eVM1

Operating an eVM1 is very much like operating a conventional circuit-breaker. Either remote or local operation can be enabled by means of a key switch integrated in the human-machine interface (HMI) unit on the door of the LV compartment. Red and green LEDs show the actual positions of the

7	HMI units are provided on the eVM1 breaker (center) and on the panel door (bottom)



breaker, disconnecting truck and grounding switch. Behind a window in the door is another HMI 7 that displays breaker and protection statuses and permits direct operation of the eVM1 in the withdrawn position.

Status display and protection settings

The HMI on the door of the LV compartment has an insulated RS485 connection where a laptop can be plugged in to access, with the help of the configuration tool 8, all status information, such as positions of the switching devices, or the 'ready' status of the eVM1. Possible readings include the currents in all the phases and the ground-fault current. The breaker can also be fully configured and prepared for testing using this tool.

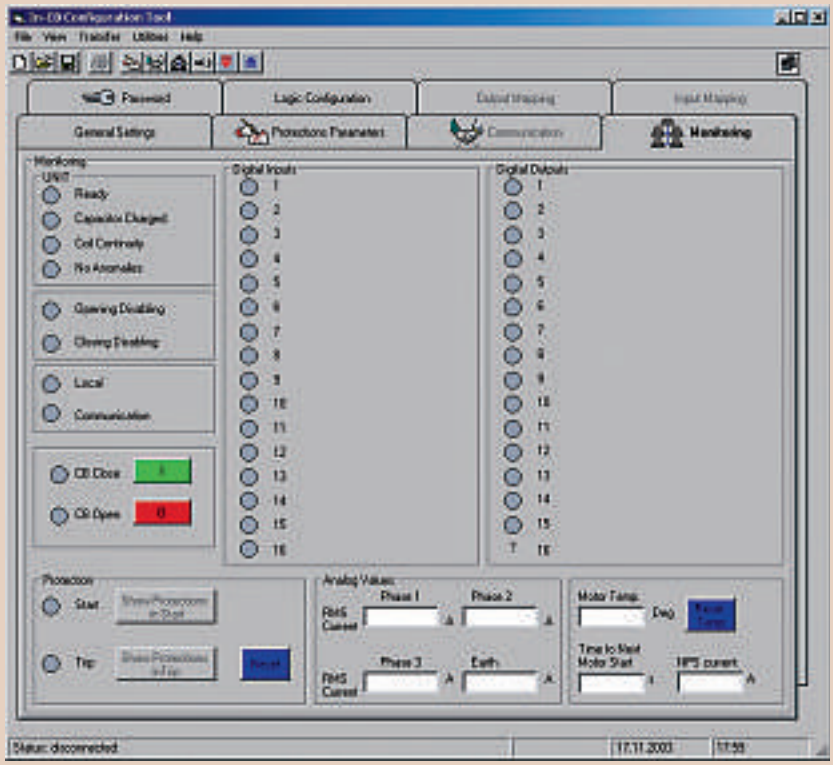
If a protection relay trips the breaker, the relay has to be reset before the breaker can be closed again. This can be done either using the Configuration Tool or by pressing the reset button on the HMI on the LV compartment door.

The tool can also be used to select, parameterize and show the status of the protection. Users can choose from a range of protection functions:

- Phase overcurrent instantaneous
- Phase overcurrent definite time high/low/inverse
- Earth fault current instantaneous
- Earth fault current definite time high/low/inverse
- Thermal image overload protection in motors
- Motor start protection (adiabatic characteristic)
- Blocking rotor (definite time characteristic)
- Unbalanced motor load
- Number of motor starts

These functions, plus the display of measured values and the protection configuration, can also be initiated remotely via bus communication.

8 Configuration tool for accessing all status information, such as positions of the switching devices



Designed to make substations simpler

The new concept employed by ABB in the eVM1 shows just how simple and straightforward a medium-voltage panel can be today while still combining all of the functionality required for the most common applications. Just installing the eVM1 for conventional outgoing feeders is effective in reducing the present-day complexity of switchgear installations. Additional equipment is required only for those panels requiring more complex protection schemes or in special cases, such as when conventional transformers are needed to bill metering.

By combining user-friendly operation and configuration with perfect matching of components and in-factory testing of the breaker together with protection schemes to minimize malfunction, the eVM1 represents another big step toward simpler and easier-to-use, as well as more reliable and safer, switchgear.

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