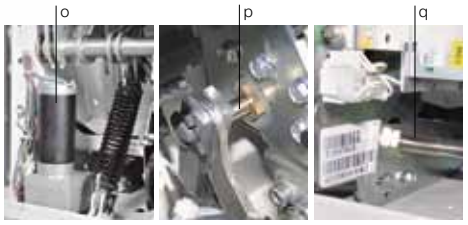
The smart eVolution

eVD4 brings simplicity and reliability to medium-voltage distribution networks

CALOGERO SAELI, CALLISTO GATTI, CARLO GEMME, EMILIA DANERI, CARLO CEREDA – Over the last decade, medium-voltage distribution networks have experienced significant changes thanks to the continuing evolution in technology. ABB is leading this evolution by providing customers with new products, such as Relion® protection and control devices, current and voltage sensors, and vacuum circuit breakers with embedded poles, all incorporating state-of-the-art ABB technologies. ABB has used these technologies to create an automatic circuit breaker that features onboard sensors and the RBX615 protection and control unit. Known as the eVD4, it enables simpler switchboard design and specification, faster installation, higher reliability and reduced maintenance needs and life-cycle costs, while increased standardization contributes to less complex switchgear and systems.

1 PCM600 is IEC 61850 compliant, which simplifies IED engineering and enables information exchange with other IEC 61850-compliant tools.

a Pole with vacuum interrupter
b Relay signals
c Sensor: Rogowski coil or combisensor
d Truck for the withdrawable circuit breaker
e RBX615 control and protection relay
f Opening push button
g Operating mechanism charging lever
h Open/closed mechanical signaling device
i Operating mechanism spring charging geared motor
j Plug for auxiliary circuits (withdrawable circuit-breaker only)
k Closing push button
l Charged /discharged spring mechanical signaling device
m Mechanical operation counter
n Mechanical operating mechanism



o Racking-in and racking-out geared motor (withdrawable circuit-breaker only)
p Circuit-breaker open-closed proximity sensor
q Charged /discharged spring proximity sensor

Recently, the medium-voltage (MV) world has seen a strong trend toward the evolution of new technologies that are enabling the development of new solutions to meet the present and future needs of distribution networks. The IEC 61850 standard, for example, is driving innovation in energy distribution devices, enabling new functionalities and new architectures for MV switchgear while increasing standardization. Products featuring a higher degree of integration, component standardization and greater overall versatility are now available on the market. Not only do they improve reliability, but they also reduce the time and effort needed for installation and maintenance.

ABB has pioneered many of these new technologies in its quest to develop new products and product series for the MV primary distribution environment.

One such product series, the innovative eVD4 automatic circuit breaker family (see title picture), has been specifically developed to enable easy, flexible and reliable MV switchgear projects, from the specification, tendering, engineering and production phases right through to the installation, commissioning, testing and maintenance phases.

The eVD4 series combines innovative ABB technologies in the field of mechanics, electronics and sensors. The result is a highly integrated device that combines measurement, protection and control capability with primary power disconnection, switching and interruption technology.

Innovation and a sound foundation of proven technology

The eVD4 is based on ABB's VD4 mechanically actuated vacuum MV circuit breaker and the new Relion® product and sensor technologies → 1. Since its introduction in 2003, the VD4 has a global installed base of over 250,000 units, and is characterized by its excellent reliability and versatility in a vast range of applications.

The RBX615 protection and control unit based on ABB's Relion technology is an intelligent electronic device (IED) dedicated to the protection, control, measurement and supervision of utility substations and industrial electrical systems. It is installed into the chassis of the eVD4 as a plug-in device via a docking unit.

The RBX615 unit guarantees the general protection of overhead and cable lines and distribution substation busbar systems, and it is suitable for any radial distribution network regardless of the grounding principle. The digital inputs and outputs (I/Os) and the communica-

> The innovative eVD4 automatic circuit breaker family has been developed specifically to enable easy, flexible and reliable MV switchgear projects.

2 Comparing a fully automatic eVD4 breaker with a standard MV circuit breaker in all stages of the product life cycle

Specification
The high level of flexibility of the eVD4 simplifies specification requirements.
In other words:
– There is no need to define any sensor parameters; the rating of the sensors is derived from the rating of the circuit breaker, whereas the type of sensors (only current or combined current and voltage version) is derived from the protection profile.
– All RBX615 preconfigurations can be customized to provide the best match to the network requirements.

Supply management
Rather than a number of separate orders, just one single order and one unique reference is required to ensure the delivery of a complete MV switchgear solution.

Fast delivery
The highly technical production line combined with component standardization enables ABB to guarantee the same delivery time for the eVD4 as for a standard circuit breaker.

Installation
The eVD4 is a ready-to-install solution. As the sensors are an integrated part of the complete unit, no wiring or additional work is needed; all the relay wiring is instantaneously connected by the circuit-breaker plug.

Reduced effort and time for engineering and wiring
As an integrated solution, a large proportion of the switchgear wiring is built into the circuit breaker, which results in a more standardized product. The amount of wiring destined for the low-voltage compartment is limited and the risk of wiring errors is significantly reduced. This in turn makes a complete switchgear solution faster and easier to engineer.

Reduced effort for factory acceptance test (FAT) with increased safety and reliability
A fully tested and integrated solution with fewer switchgear wires reduces the effort needed to complete compulsory FAT tests.

Easy maintenance, the optimization of spare part stocks and reduced mean time to repair (MTTR)
The eVD4 is built from standard components that can be used across a wide range of applications. In addition, with just a few variations, all circuit breaker models within the eVD4 family are covered and so only a small number of spare parts need to be kept in stock. All accessories are readily available and can be easily maintained. This integrated solution allows fast system recovery in case of failure, and all the core components of the switchgear will be replaced by simply replacing the eVD4.

The RBX615 protection and control unit is integrated into the eVD4 and performs the monitoring, control and diagnostic functions.

tion channels, which are available within switchgear's low-voltage (LV) compartment, can be accessed through the circuit-breaker plug that is connected to the LV compartment socket.

The sensors, mounted on the circuit-breaker poles, measure the currents and voltages needed for protection and control in MV power systems. The technology used to develop the sensors has resulted in a reduction in equipment size, improved equipment performance and an increased level of standardization. This combination of sensors and IED (the RBX615) enables the accurate and reliable monitoring and registering of network parameters while providing better protection for both operating personnel and the substation equipment.

The advantages of a fully automatic eVD4 breaker over a standard MV circuit breaker in all stages of the product life cycle are given in → 2.

The eVD4 covers most common MV circuit-breaker ratings: Nominal voltage up to 17.5 kV; nominal current up to 2,500 A; and breaking capacity up to 40 kA. The RBX615 relay can be ordered with five different protection profiles, each of which correspond to a particular set of protection functions that require both current and voltage measurements. Because it is integrated into the eVD4, the design of the relay has been optimized specifically so that it can perform the monitoring, control and diagnostic functions of the eVD4.

eVD4 structure overview

The design of the new eVD4 vacuum circuit breaker more than satisfies the requirements of simplicity (it is characterized by a small number of highly reliable components and can be customized with a wide range of easily and rapidly installed accessories) and safety (a sturdy metal frame fixes the poles and the operating mechanism are fixed).

Operating mechanism

The operating mechanism contains a spring to store the energy needed for the mechanical opening and closing releases and dedicated interlocks. Correct operation requires the immediate availability of stored energy, which can (in the case of the eVD4) be low because of lightweight interrupter contacts and reduced contact travel for switching. This limits the wear on the system and makes the circuit breaker practically maintenance-free. Up to 30,000 open/close operations are possible over the lifetime of the eVD4.

Proximity sensors

Proximity sensors allow the eVD4 to determine the status of its moving parts with high reliability. For example, these sensors detect the breaker's open/close status, the spring's charge/discharge state and the position of the truck. This information is then sent to the RBX615 relay via a dedicated wire link.

An enhanced auxiliary circuit plug

The eVD4 plug has to provide a reliable connection not only for the circuit breaker's auxiliary circuits but also for the relay connections, ie, the communication channels, the I/O signals and the residual current sensor connections → 3. This is achieved using an enhanced plug comprising 58 pins, plus separate communication channels (two electrical Ethernet ports are shown on the right of the plug).

3 The enhanced auxiliary circuit plug of the eVD4 circuit breaker

4 The RBX615 relay is based on ABB's Relion® technology

The eVD4 has been designed to fully exploit the potential of the IEC 61850 standard and generic object-oriented substation events (GOOSE) technology, including the horizontal high-speed relay-to-relay communication, by means of an inter-panel bus. However, when required, a traditional point-to-point hard-wired connection to the RBX615 relay is possible through 12 digital inputs and eight digital outputs in the plug.

To enable easy installation of the eVD4, a dedicated panel socket accessory has been designed.

The RBX615 and HMI

The RBX615 is a general purpose relay based on ABB's Relion® technology and is designed specifically for operation in the eVD4 ➔ 4. The shape and pin layout of the relay have been optimized to enable a straightforward plug-in interface to the breaker using a dedicated docking unit.

It is available with five different preconfigured protection profiles, three of which focus on feeder protection and the remaining two are mainly intended for motor protection ➔ 5. The preconfigurations can be fully customized by the protection and control IED manager tool, PCM600 [1], and the application configuration tool (ACT), a graphical tool that enables the easy and simple modification of application logic. Several logic blocks are available to meet every substation need. Modifying the parameters of the protection and control logic provided in the preconfigurations can also be carried out via a human machine interface (HMI) located on the relay front panel ➔ 6.

This interface shows the single-line diagram (SLD) on the left with the relay menu on the right. The SLD can be edited using the graphical display editor tool inside the PCM600. The symbols indicated are dynamically linked to the related object (eg, circuit breaker, circuit-breaker racking gear, earthing switch, line disconnector) and their status is shown in the display. Moreover, the status of these objects can be easily controlled from the HMI.

The Ethernet port on the HMI facilities a point-to-point connection between the relay and a PC. With such a connection, the HMI is automatically displayed in the Web browser, allowing the user to modify the parameters of the protection functions as well as download disturbance records and several other features. No additional software needs to be installed on the client PC to communicate with the protection and control device. Two communication channels allow the relay to communicate with the process system. Even though the RBX615 is IEC 61850 compliant it also implements Modbus® TCP/IP. Other communication protocols will be available in the future.

The eVD4 fully exploits the potential of the IEC 61850 standard and GOOSE technology, including the horizontal high-speed relay-to-relay communication.

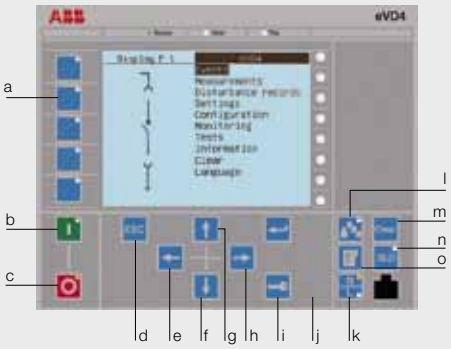
Footnote

1 PCM600 is IEC 61850 compliant, which simplifies IED engineering and enables information exchange with other IEC 61850-compliant tools.

5 The RBX615 relay can accommodate five different preconfigured protection profiles

Description	Configuration
Nondirectional overcurrent protection and nondirectional earth fault protection	Feeder 1 (F1)
Nondirectional overcurrent protection and directional earth fault protection based on measurement of the phase voltages	Feeder 2 (F2)
Directional overcurrent protection, directional earth fault protection based on measurement of the phase voltages, and undervoltage and overvoltage protection	Feeder 3 (F3)
Motor protection based on the current measurement	Motor 1 (M1)
Motor protection based on the current and voltage measurements	Motor 2 (M2)

6 The parameters of the protection and control logic provided in the preconfigurations are modified using the relay HMI



a Application function keys
b Closing
c Opening
d Escape
e Left
f Down
g Up
h Right
i Key
j Confirm
k Local/Remote
l LED page key
m Cancel
n Single-line diagram
o Menu

Two types of sensors are used in the eVD4: current sensors (based on the Rogowski coil principle) and a combined current and voltage sensor known as a combi-sensor.

Sensors

The latest and most advanced sensor technology is used in eVD4 automatic circuit breakers. Two types of sensors can be installed on board the eVD4 – current sensors (based on the Rogowski coil principle) and a combined current and voltage sensor known as a combi-sensor ➔ 7. The choice of sensor depends on the protection profile of the RBX615.

The sensors are used to:
- Convert large currents and voltages in the primary circuit of the network to an appropriate signal for secondary circuit equipment (ie, the protection relay RBX615)
- Insulate primary and secondary circuits from each other
- Protect secondary equipment from the harmful effects of the large currents and voltages that might occur on the primary side during a short circuit in the network

The entire range of currents and voltages is covered with just three sensor sizes, which extend up to the maximum rated current and voltage of the circuit breaker. A broken circuit or a short circuit in the signal cable is not dangerous and will cause no damage.

The current sensor consists of a Rogowski coil, a uniform winding on a closed circular support with a constant cross section and no ferromagnetic core ➔ 8. The voltage induced in the winding (the transmitted signal) is directly proportional to the variation in the let-through current. These sensors are characterized by the absence of saturation and hysteresis phenomena because there is no iron in the Rogowski coil and this guarantees excellent linearity. The current sensors for the eVD4 breaker output measurements are linear up to the maximum value set for the protection thresholds.

The voltage sensor uses a capacitive divider for voltage indication ➔ 9. In other words, a cylindrical metal electrode is molded into the sensor and faces the circuit-breaker bushing. The output signal is a voltage directly proportional to the primary voltage. As with the current sensors, the voltage sensors are characterized by the absence of ferroresonance phenomena and insensitivity to the effects of DC components.

The advantages of using integrated sensors in the eVD4 breaker include linear measurements and versatile protection; safety; small power comsumption; and that they are an environmentally friendly solution.

Linear measurements and versatile protection

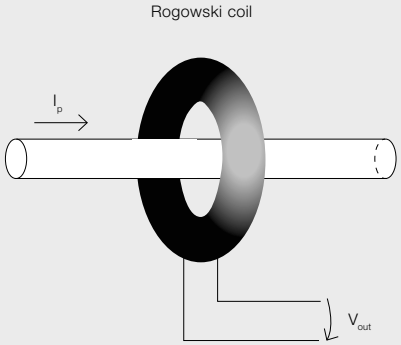
With no resonance and hysteresis phenomena the sensors exhibit good dynamic performance and are linear right up to the highest currents and voltages. As a result, they ensure high protection performance and enable multisided disturbance analysis.

Safety

The nominal value of the transmitted signal is low enough to be harmless to both people and secondary equipment, even when the highest currents and voltages occur on the primary side. A break or short circuit in the signal cable poses no danger and will cause no damage.

7 The choice of current or voltage sensors depends on the relay protection profile

8 The current sensors are based on the Rogowski coil principle



The transmitted signal is a voltage:

$$V_{out} = M\frac{di_p}{dt}$$

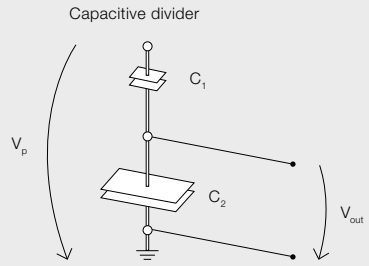
For a sinusoidal current under steady state conditions the voltage is:

$$V_{out} = M \cdot j \cdot \omega \cdot I_p$$

The signal is a sinusoidal voltage, proportional to the current, with 90° phase shift (lead).

In all cases, even if the primary current is non-sinusoidal, a signal reproducing the actual primary current waveform is obtained by integrating the transmitted signal.

9 The voltage sensors use a capacitive divider for voltage indication



Transmitted signal from a voltage divider:

The transmitted signal is:

$$V_{out} = \frac{C_1}{C_1 + C_2} V_p \quad \text{(capacitive divider)}$$

In all cases, the transmitted signal reproduces the actual primary voltage waveform.

Small power consumption

The efficiency of a sensor is high compared with that of instrument transformers. In addition, there are no losses in the secondary cabling. These savings contribute to increasing the life span of the equipment, and in a utility such savings are significant.

Environmentally friendly

In constructing the sensors, fewer raw materials are needed and power consumption is negligible.

The eVD4 is a major step forward in terms of performance, simplicity, reliability, safety and cost effectiveness.

Taking MV switchgear into the future

ABB's new eVD4 automatic circuit breaker is a key element for the creation of simple, reliable and safe MV switchgear. Full compliance with the new IEC 61850 standard and GOOSE functionality assure compatibility with new substation communication systems. The entire switchgear life cycle is optimized by the adoption of the eVD4. Starting from easier specification and ordering, to the drastically reduced complexity of the switchgear in terms of engineering, wiring and testing, to the commissioning and maintenance of the panel, the eVD4 is a major step forward in terms of performance, simplicity, reliability, safety and cost effectiveness.

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Title picture

The title picture shows ABB's eVD4 automatic circuit breaker with HMI for medium-voltage switchgear projects.