

Circuit breaker

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A **circuit breaker** is an automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Unlike a fuse, which operates once and then has to be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect an individual household appliance up to large switchgear designed to protect high voltage circuits feeding an entire city.

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A 2 pole miniature circuit breaker

Origins

An early form of circuit breaker was described by Edison in an 1879 patent application, although his commercial power distribution system used fuses.^[1] Its purpose was to protect lighting circuit wiring from accidental short-circuits and overloads.

Operation

All circuit breakers have common features in their operation, although details vary substantially depending on the voltage class, current rating and type of the circuit breaker.

The circuit breaker must detect a fault condition; in low-voltage circuit breakers this is usually done within the breaker enclosure. Circuit breakers for large currents or high voltages are usually arranged with pilot devices to sense a fault current and to operate the trip opening mechanism. The trip solenoid that releases the latch is usually energized by a separate battery, although some high-voltage circuit breakers are self-contained with current transformers, protection relays, and an internal control power source.

Once a fault is detected, contacts within the circuit breaker must open to interrupt the circuit; some mechanically stored energy within the breaker is used to separate the contacts, although some of the energy required may be obtained from the fault current itself. The stored energy may be in the form of springs or compressed air. Small circuit breakers may be manually operated; larger units have solenoids to trip the mechanism, and electric motors to restore energy to the springs.

The circuit breaker contacts must carry the load current without excessive heating, and must also withstand the heat of the arc produced when interrupting the circuit. Contacts are made of copper or copper alloys, silver alloys, and other materials. Service life of the contacts is limited by the erosion due to interrupting the arc. Miniature circuit breakers are usually discarded when the contacts are worn, but power circuit breakers and high-voltage circuit breakers have replaceable contacts.

When a current is interrupted, an arc is generated - this arc must be contained, cooled, and extinguished in a controlled way, so that the gap between the contacts can again withstand the voltage in the circuit. Different circuit breakers use vacuum, air, insulating gas, or oil as the medium in which the arc forms. Different techniques are used to extinguish the arc including:

- Lengthening of the arc
- Intensive cooling (in jet chambers)
- Division into partial arcs
- Zero point quenching
- Connecting capacitors in parallel with contacts in DC circuits

Finally, once the fault condition has been cleared, the contacts must again be closed to restore power to the interrupted circuit.

Arc interruption

Miniature low-voltage circuit breakers use air alone to extinguish the arc. Larger ratings will have metal plates or non-metallic arc chutes to divide and cool the arc. Magnetic blowout coils deflect the arc into the arc chute.

In larger ratings, oil circuit breakers rely upon vaporization of some of the oil to blast a jet of oil through the arc.^[2]

Gas (usually sulfur hexafluoride) circuit breakers sometimes stretch the arc using a magnetic field, and then rely upon the dielectric strength of the sulfur hexafluoride (SF₆) to quench the stretched arc.

Vacuum circuit breakers have minimal arcing (as there is nothing to ionize other than the contact material), so the arc quenches when it is stretched a very small amount (<2-3 mm). Vacuum circuit breakers are frequently used in modern medium-voltage switchgear to 35,000 volts.

Air circuit breakers may use compressed air to blow out the arc, or alternatively, the contacts are rapidly swung into a small sealed chamber, the escaping of the displaced air thus blowing out the arc.

Circuit breakers are usually able to terminate all current very quickly: typically the arc is extinguished between 30 ms and 150 ms after the mechanism has been tripped, depending upon age and construction of the device.

Short circuit current

Circuit breakers are rated both by the normal current that are expected to carry, and the maximum short-circuit current that they can safely interrupt.

Under short-circuit conditions, a current many times greater than normal can exist (see maximum prospective short circuit current). When electrical contacts open to interrupt a large current, there is a tendency for an arc to form between the opened contacts, which would allow the current to continue. Therefore, circuit breakers must incorporate various features to divide and extinguish the arc.

The maximum short-circuit current that a breaker can interrupt is determined by testing. Application of a breaker in a circuit with a prospective short-circuit current higher than the breaker's interrupting capacity rating may result in failure of the breaker to safely interrupt a fault. In a worst-case scenario the breaker may successfully interrupt the fault, only to explode when reset, injuring the technician.

Miniature circuit breakers used to protect control circuits or small appliances may not have sufficient interrupting capacity to use at a panelboard; these circuit breakers are called "supplemental circuit protectors" to distinguish them from distribution-type circuit breakers.

Types of circuit breaker

Many different classifications of circuit breakers can be made, based on their features such as voltage class, construction type, interrupting type, and structural features.

Low voltage circuit breakers

Low voltage (less than 1000 V_{AC}) types are common in domestic, commercial and industrial application, include:

- MCB (Miniature Circuit Breaker)—rated current not more than 100 A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category.
- MCCB (Molded Case Circuit Breaker)—rated current up to 1000 A. Thermal or thermal-magnetic operation. Trip current may be adjustable in larger ratings.
- Low voltage power circuit breakers can be mounted in multi-tiers in LV switchboards or switchgear cabinets.

The characteristics of LV circuit breakers are given by international standards such as IEC 947. These circuit breakers are often installed in draw-out enclosures that allow removal and interchange without dismantling the switchgear.

Large low-voltage molded case and power circuit breakers may have electrical motor operators, allowing them to be tripped (opened) and closed under remote control. These may form part of an automatic transfer switch system for standby power.

Low-voltage circuit breakers are also made for direct-current (DC) applications, for example DC supplied for subway lines. Special breakers are required for direct current because the arc does not have a natural tendency to go out on each half cycle as for alternating current. A direct current circuit breaker will have blow-out coils which generate a magnetic field that rapidly stretches the arc when interrupting direct current.

Small circuit breakers are either installed directly in equipment, or are arranged in a breaker panel.

The 10 ampere DIN rail-mounted thermal-magnetic miniature circuit breaker is the most common style in modern domestic consumer units and commercial electrical distribution boards throughout Europe. The design includes the following components:

1. Actuator lever - used to manually trip and reset the circuit breaker. Also indicates the status of the circuit breaker (On or Off/tripped). Most breakers are designed so they can still trip even if the lever is held or locked in the "on" position. This is sometimes referred to as "free trip" or "positive trip" operation.
2. Actuator mechanism - forces the contacts together or apart.
3. Contacts - Allow current when touching and break the current when moved apart.
4. Terminals
5. Bimetallic strip
6. Calibration screw - allows the manufacturer to precisely adjust the trip current of the device after assembly.
7. Solenoid
8. Arc divider / extinguisher

Magnetic circuit breaker

Magnetic circuit breakers use a solenoid (electromagnet) whose pulling force increases with the current. The circuit breaker contacts are held closed by a latch. As the current in the solenoid increases beyond the rating of the circuit breaker, the solenoid's pull releases the latch which then allows the contacts to open by spring action. Some types of magnetic breakers incorporate a hydraulic time delay feature using a viscous fluid. The core is restrained by a spring until the current exceeds the breaker rating. During an overload, the speed of the solenoid motion is restricted by the fluid. The delay permits brief current surges beyond normal running current for motor starting, energizing equipment, etc. Short circuit currents provide sufficient solenoid force to release the latch regardless of core position thus bypassing the delay feature. Ambient temperature affects the time delay but does not affect the current rating of a magnetic breaker.

Thermomagnetic circuit breaker

Thermomagnetic circuit breakers, which are the type found in most distribution boards, incorporate both techniques with the electromagnet responding instantaneously to large surges in current (short circuits) and the bimetallic strip responding to less extreme but longer-term over-current conditions.

Rated circuits

Circuit breakers are rated both by the normal current that are expected to carry, and the maximum short-circuit current that they can safely interrupt.

Under short-circuit conditions, a current many times greater than normal can exist (see maximum prospective short circuit current). When electrical contacts open to interrupt a large current, there is a tendency for an arc to form between the opened contacts, which would allow the current to continue. Therefore, circuit breakers must incorporate various features to divide and extinguish the arc. In air-insulated and miniature breakers an *arc chute* structure consisting (often) of metal plates or ceramic ridges cools the arc, and magnetic blowout coils deflect the arc into the arc chute. Larger circuit breakers such as those used in electrical power distribution may use vacuum, an inert gas such as sulphur hexafluoride or have



Front panel of a 1250 A air circuit breaker manufactured by ABB. This low voltage power circuit breaker can be withdrawn from its housing for servicing. Trip characteristics are configurable via DIP switches on the front panel.

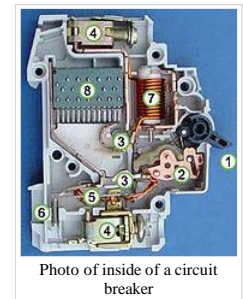


Photo of inside of a circuit breaker

contacts immersed in oil to suppress the arc.

The maximum short-circuit current that a breaker can interrupt is determined by testing. Application of a breaker in a circuit with a prospective short-circuit current higher than the breaker's interrupting capacity rating may result in failure of the breaker to safely interrupt a fault. In a worst-case scenario the breaker may successfully interrupt the fault, only to explode when reset, injuring the technician.

International Standard IEC 60898-1 and European Standard EN 60898-1 define the *rated current* I_n of a circuit breaker for low voltage distribution applications as the current that the breaker is designed to carry continuously (at an ambient air temperature of 30 °C). The commonly-available preferred values for the rated current are 6 A, 10 A, 13 A, 16 A, 20 A, 25 A, 32 A, 40 A, 50 A, 63 A, 80 A and 100 A^[3] (Renard series, slightly modified to include current limit of British BS 1363 sockets). The circuit breaker is labeled with the rated current in ampere, but without the unit symbol "A". Instead, the ampere figure is preceded by a letter "B", "C" or "D" that indicates the *instantaneous tripping current*, that is the minimum value of current that causes the circuit-breaker to trip without intentional time delay (i.e., in less than 100 ms), expressed in terms of I_n :

Type	Instantaneous tripping current
B	above 3 I_n up to and including 5 I_n
C	above 5 I_n up to and including 10 I_n
D	above 10 I_n up to and including 20 I_n
K	above 8 I_n up to and including 12 I_n For the protection of loads that cause frequent short duration (approximately 400 ms to 2 s) current peaks in normal operation.
Z	above 2 I_n up to and including 3 I_n for periods in the order of tens of seconds. For the protection of loads such as semiconductor devices or measuring circuits using current transformers.

Common trip breakers

When supplying a branch circuit with more than one live conductor, each live conductor must be protected by a breaker pole. To ensure that all live conductors are interrupted when any pole trips, a "common trip" breaker must be used. These may either contain two or three tripping mechanisms within one case, or for small breakers, may externally tie the poles together via their operating handles. Two pole common trip breakers are common on 120/240 volt systems where 240 volt loads (including major appliances or further distribution boards) span the two live wires. Three-pole common trip breakers are typically used to supply three-phase electric power to large motors or further distribution boards.



Three pole common trip breaker for supplying a three-phase device. This breaker has a 2 A rating

Medium-voltage circuit breakers

Medium-voltage circuit breakers rated between 1 and 72 kV may be assembled into metal-enclosed switchgear line ups for indoor use, or may be individual components installed outdoors in a substation. Air-break circuit breakers replaced oil-filled units for indoor applications, but are now themselves being replaced by vacuum circuit breakers (up to about 35 kV). Like the high voltage circuit breakers described below, these are also operated by current sensing protective relays operated through current transformers. The characteristics of MV breakers are given by international standards such as IEC 62271. Medium-voltage circuit breakers nearly always use separate current sensors and protection relays, instead of relying on built-in thermal or magnetic overcurrent sensors.

Medium-voltage circuit breakers can be classified by the medium used to extinguish the arc:

- Vacuum circuit breaker—With rated current up to 3000 A, these breakers interrupt the current by creating and extinguishing the arc in a vacuum container. These can only be practically applied for voltages up to about 35,000 V, which corresponds roughly to the medium-voltage range of power systems. Vacuum circuit breakers tend to have longer life expectancies between overhaul than do air circuit breakers.
- Air circuit breaker—Rated current up to 10,000 A. Trip characteristics are often fully adjustable including configurable trip thresholds and delays. Usually electronically controlled, though some models are microprocessor controlled via an integral electronic trip unit. Often used for main power distribution in large industrial plant, where the breakers are arranged in draw-out enclosures for ease of maintenance.
- SF6 circuit breakers extinguish the arc in a chamber filled with sulfur hexafluoride gas.

Medium-voltage circuit breakers may be connected into the circuit by bolted connections to bus bars or wires, especially in outdoor switchyards. Medium-voltage circuit breakers in switchgear line-ups are often built with draw-out construction, allowing the breaker to be removed without disturbing the power circuit connections, using a motor-operated or hand-cranked mechanism to separate the breaker from its enclosure.

High-voltage circuit breakers

Electrical power transmission networks are protected and controlled by high-voltage breakers. The definition of "high voltage" varies but in power transmission work is usually thought to be 72,500 V or higher, according to a recent definition by the International Electrotechnical Commission (IEC). High-voltage breakers are nearly always solenoid-operated, with current sensing protective relays operated through current transformers. In substations the protection relay scheme can be complex, protecting equipment and busses from various types of overload or ground/earth fault.

High-voltage breakers are broadly classified by the medium used to extinguish the arc.

- Bulk oil
- Minimum oil
- Air blast
- SF₆

Some of the manufacturers are ABB, AREVA, Cutler-Hammer (Eaton), Siemens, Toshiba, Schneider-Electric and others.

Circuit breaker can be classified as "live tank", where the enclosure that contains the breaking mechanism is at line potential, or *dead tank* with the enclosure at earth potential. High-voltage AC circuit breakers are routinely available with ratings up to 765,000 volts.

High-voltage circuit breakers used on transmission systems may be arranged to allow a single pole of a three-phase line to trip, instead of tripping all three poles; for some classes of faults this improves the system stability and availability.

Sulfur Hexafluoride (SF6) high-voltage circuit-breakers

High-voltage circuit-breakers have greatly changed since they were first introduced about 40 years ago, and several interrupting principles have been developed that have contributed successively to a large reduction of the operating energy. These breakers are available for indoor or outdoor applications, the latter being in the form of breaker poles housed in ceramic insulators mounted on a structure.



400kV SF6 circuit breakers

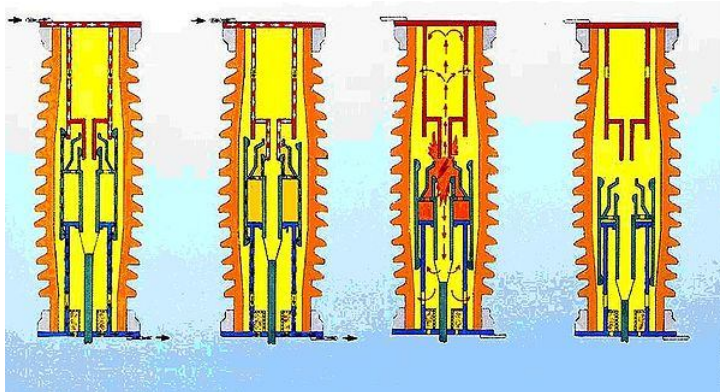
Current interruption in a high-voltage circuit-breaker is obtained by separating two contacts in a medium, such as SF₆, having excellent dielectric and arc quenching properties. After contact separation, current is carried through an arc and is interrupted when this arc is cooled by a gas blast of sufficient intensity.

Gas blast applied on the arc must be able to cool it rapidly so that gas temperature between the contacts is reduced from 20,000 K to less than 2000 K in a few hundred microseconds, so that it is able to withstand the transient recovery voltage that is applied across the contacts after current interruption. Sulphur hexafluoride is generally used in present high-voltage circuit-breakers (of rated voltage higher than 52 kV).

In the 1980s and 1990s, the pressure necessary to blast the arc was generated mostly by gas heating using arc energy. It is now possible to use low energy spring-loaded mechanisms to drive high-voltage circuit-breakers up to 800 kV.

Brief history

The first patents on the use of SF₆ as an interrupting medium were filed in Germany in 1938 by Vitaly Grosse (AEG) and independently later in the USA in July 1951 by H.J. Lingal, T.E. Browne and A.P. Storm (Westinghouse). The first industrial application of SF₆ for current interruption dates back to 1953. High-voltage 15 kV to 161 kV load switches were developed with a breaking capacity of 600 A. The first high-voltage SF₆ circuit-breaker built in 1956 by Westinghouse, could interrupt 5 kA under 115 kV, but it had 6 interrupting chambers in series per pole. In 1957, the puffer-type technique was introduced for SF₆ circuit breakers where the relative movement of a piston and a cylinder linked to the moving part is used to generate the pressure rise necessary to blast the arc via a nozzle made of insulating material (figure 1). In this technique, the pressure rise is obtained mainly by gas compression. The first high-voltage SF₆ circuit-breaker with a high short-circuit current capability was produced by Westinghouse in 1959. This dead tank circuit-breaker could interrupt 41.8 kA under 138 kV (10,000 MV·A) and 37.6 kA under 230 kV (15,000 MV·A). This performance were already significant, but the three chambers per pole and the high pressure source needed for the blast (1.35 MPa) was a constraint that had to be avoided in subsequent developments. The excellent properties of SF₆ lead to the fast extension of this technique in the 1970s and to its use for the development of circuit breakers with high interrupting capability, up to 800 kV.



The achievement around 1983 of the first single-break 245 kV and the corresponding 420kV to 550 kV and 800 kV, with respectively 2, 3, and 4 chambers per pole, lead to the dominance of SF₆ circuit breakers in the complete range of high voltages.

Several characteristics of SF₆ circuit breakers can explain their success:

- Simplicity of the interrupting chamber which does not need an auxiliary breaking chamber;
- Autonomy provided by the puffer technique;
- The possibility to obtain the highest performance, up to 63 kA, with a reduced number of interrupting chambers;
- Short break time of 2 to 2.5 cycles;
- High electrical endurance, allowing at least 25 years of operation without reconditioning;
- Possible compact solutions when used for "gas insulated switchgear" (GIS) or hybrid switchgear;
- Integrated closing resistors or synchronized operations to reduce switching over-voltages;
- Reliability and availability;
- Low noise levels.

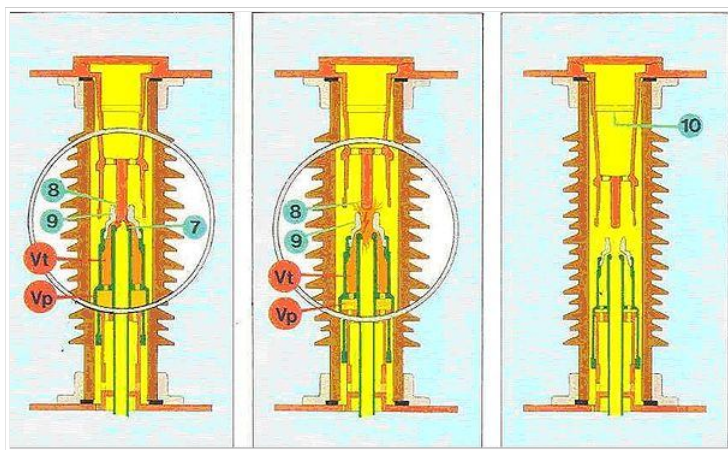
The reduction in the number of interrupting chambers per pole has led to a considerable simplification of circuit breakers as well as the number of parts and seals required. As a direct consequence, the reliability of circuit breakers improved, as verified later on by CIGRE surveys.

Thermal blast chambers

New types of SF₆ breaking chambers, which implement innovative interrupting principles, have been developed over the past 15 years, with the objective of reducing the operating energy of the circuit-breaker. One aim of this evolution was to further increase the reliability by reducing the dynamic forces in the pole. Developments since 1996 have seen the use of the self-blast technique of interruption for SF₆ interrupting chambers.

These developments have been facilitated by the progress made in digital simulations that were widely used to optimize the geometry of the interrupting chamber and the linkage between the poles and the mechanism.

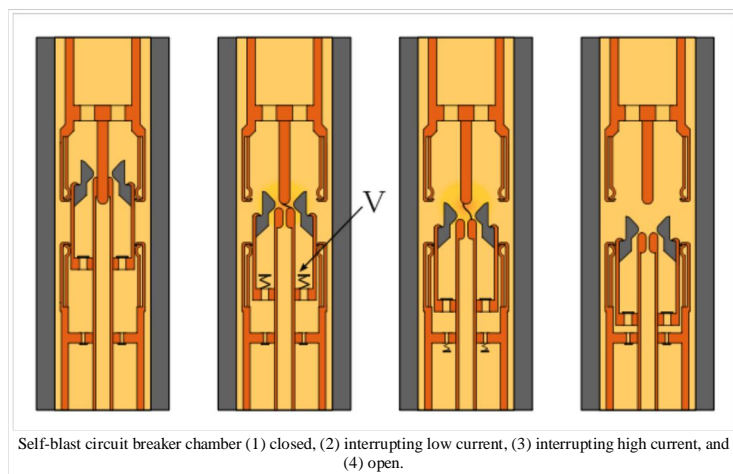
This technique has proved to be very efficient and has been widely applied for high voltage circuit breakers up to 550 kV. It has allowed the development of new ranges of circuit breakers operated by low energy spring-operated mechanisms.



The reduction of operating energy was mainly achieved by the lowering energy used for gas compression and by making increased use of arc energy to produce the pressure necessary to quench the arc and obtain current interruption. Low current interruption, up to about 30% of rated short-circuit current, is obtained by a puffer blast.

Self-blast chambers

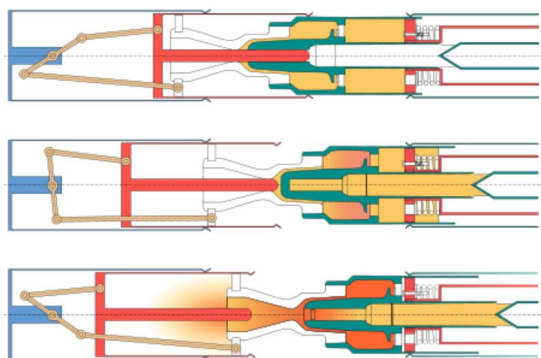
Further development in the thermal blast technique was made by the introduction of a valve between the expansion and compression volumes. When interrupting low currents the valve opens under the effect of the overpressure generated in the compression volume. The blow-out of the arc is made as in a puffer circuit breaker thanks to the compression of the gas obtained by the piston action. In the case of high currents interruption, the arc energy produces a high overpressure in the expansion volume, which leads to the closure of the valve and thus isolating the expansion volume from the compression volume. The overpressure necessary for breaking is obtained by the optimal use of the thermal effect and of the nozzle clogging effect produced whenever the cross-section of the arc significantly reduces the exhaust of gas in the nozzle. In order to avoid excessive energy consumption by gas compression, a valve is fitted on the piston in order to limit the overpressure in the compression to a value necessary for the interruption of low short circuit currents.



This technique, known as "self-blast" has now been used extensively since 1996 for the development of many types of interrupting chambers. The increased understanding of arc interruption obtained by digital simulations and validation through breaking tests, contribute to a higher reliability of these self-blast circuit breakers. In addition the reduction in operating energy, allowed by the self blast technique, leads to longer service life.

Double motion of contacts

An important decrease in operating energy can also be obtained by reducing the kinetic energy consumed during the tripping operation. One way is to displace the two arcing contacts in opposite directions so that the arc speed is half that of a conventional layout with a single mobile contact.



The thermal and self blast principles have enabled the use of low energy spring mechanisms for the operation of high voltage circuit breakers. They progressively replaced the puffer technique in the 1980s; first in 72.5 kV breakers, and then from 145 kV to 800 kV.

Comparison of single motion and double motion techniques

The double motion technique halves the tripping speed of the moving part. In principle, the kinetic energy could be quartered if the total moving mass was not increased. However, as the total moving mass *is* increased, the practical reduction in kinetic energy is closer to 60%. The total tripping energy also includes the compression energy, which is almost the same for both techniques. Thus, the reduction of the total tripping energy is lower, about 30%, although the exact value depends on the application and the operating mechanism.

Depending on the specific case, either the double motion or the single motion technique can be cheaper. Other considerations, such as rationalization of the circuit-breaker range, can also influence the cost.

Thermal blast chamber with arc-assisted opening

In this interruption principle arc energy is used, on the one hand to generate the blast by thermal expansion and, on the other hand, to accelerate the moving part of the circuit breaker when interrupting high currents. The overpressure produced by the arc energy downstream of the interruption zone is applied on an auxiliary piston linked with the moving part. The resulting force accelerates the moving part, thus increasing the energy available for tripping.

With this interrupting principle it is possible, during high-current interruptions, to increase by about 30% the tripping energy delivered by the operating mechanism and to maintain the opening speed independently of the current. It is obviously better suited to circuit-breakers with high breaking currents such as Generator circuit-breakers.

Generator circuit-breakers

Generator circuit-breakers are connected between a generator and the step-up voltage transformer. They are generally used at the outlet of high power generators (100 MVA to 1800 MVA) in order to protect them in a reliable, fast and economic manner. Such circuit breakers must be able to allow the passage of high permanent currents under continuous service (6.3 kA to 40 kA), and have a high breaking capacity (63 kA to 275 kA). They belong to the medium voltage range, but the TRV withstand capability required by ANSI/IEEE Standard C37.013 is such that the interrupting principles developed for the high-voltage range must be used. A particular embodiment of the thermal blast technique has been developed and applied to generator circuit-breakers. The self-blast technique described above is also widely used in SF₆ generator circuit breakers, in which the contact system is driven by a low-energy, spring-operated mechanism. An example of such a device is shown in the figure below; this circuit breaker is rated for 17.5 kV and 63 kA.

Evolution of tripping energy

The operating energy has been reduced by 5 to 7 times during this period of 27 years. This illustrates well the great progress made in this field of interrupting techniques for high-voltage circuit-breakers.

Future perspectives

In the near future, present interrupting technologies can be applied to circuit-breakers with the higher rated breaking currents (63 kA to 80 kA) required in some networks with increasing power generation.

Self blast or thermal blast circuit breakers are nowadays accepted world wide and they have been in service for high voltage applications for about 15 years, starting with the voltage level of 72.5 kV^[4]. Today this technique is also available for the voltage levels 420/550/800 kV.

Other breakers

The following types are described in separate articles.

- Breakers for protections against earth faults too small to trip an over-current device:
 - Residual-current device (RCD, formerly known as a *Residual Current Circuit Breaker*) — detects current imbalance, but does not provide over-current protection.
 - Residual Current Breaker with Over-current protection (RCBO) — combines the functions of an RCD and an MCB in one package. In the United States and Canada, panel-mounted devices that combine ground (earth) fault detection and over-current protection are called Ground Fault Circuit Interrupter (GFCI) breakers; a wall mounted outlet device providing ground fault detection only is called a GFI.
 - Earth leakage circuit breaker (ELCB) — This detects earth current directly rather than detecting imbalance. They are no longer seen in new installations for various reasons.
- Autorecloser — A type of circuit breaker which closes again after a delay. These are used on overhead power distribution systems, to prevent short duration faults from causing sustained outages.
- Polyswitch (polyfuse) — A small device commonly described as an automatically resetting fuse rather than a circuit breaker.

See also

- Protective Device Coordination
- Residual current device
- Earth leakage circuit breaker
- Earthing system
- Domestic AC power plugs and sockets
- Arc-fault circuit interrupter
- Insulation Monitoring Device

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 2. ^ B. M. Weedy, *Electric Power Systems Second Edition*, John Wiley and Sons, London, 1972, ISBN 0471924458 pp. 428-430
 3. ^ http://bonle.en.alibaba.com/product/50348671/51680889/Switch/MCB_MCCB.html
 4. ^ *New interrupting and drive techniques to increase high voltage circuit breaker performance and reliability* (<http://www.aveva-td.com/solutions/liblocal/docs/Products/1061196874876-F35-2.pdf>) , CIGRE Session 1998, Paper 13-04
- BS EN 60898-1. Electrical accessories — Circuit breakers for over-current protection for household and similar installations. British Standards Institute, 2003.

External links

- How Circuit Breakers Work (<http://electronics.howstuffworks.com/circuit-breaker.htm>) .
- L. W. Brittan: *Electrical Circuit Breakers* (<http://www.maintenanceresources.com/referencelibrary/ezone/electcircuitbreak.html>)
- <http://hyperphysics.phy-astr.gsu.edu/hbase/electric/bregnd.html>

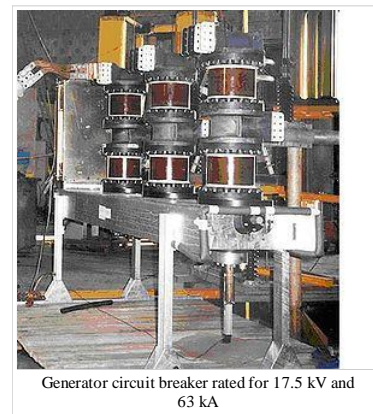


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Generator circuit breaker rated for 17.5 kV and 63 kA