Introductory Overview of High Voltage Circuit Breakers
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Definition of a circuit breaker

- A circuit breaker (CB) is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current flow. Unlike a fuse, which operates once and then must 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 a large switchgear designed to protect high voltage circuits feeding an entire city.
History and origins of CB

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

• A modern miniature circuit breaker similar to the ones now in use was patented by Brown, Boveri & Cie in 1924. Hugo Stotz, an engineer who had sold his company to BBC, was credited as the inventor of DRP (Deutsches Reichs Patent) #458392. Stotz's invention was the forerunner of the modern thermal-magnetic breaker commonly used in household-load-centers to this day.
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• Interconnection of multiple generator sources into an electrical grid required development of circuit breakers with increasing voltage ratings and increased ability to safely interrupt the increasing short circuit currents produced by networks’ severe faults.

• Simple air-break manual switches produced hazardous arcs when interrupting high currents; these gave a way to oil-enclosed contacts, and various other forms using directed flow of pressurized air, or of pressurized oil, to cool and interrupt the arc. By 1935, the specially constructed circuit breakers used at the Boulder Dam project used eight series breaks and pressurized oil flow to interrupt faults of up to 2,500 MVA, in three cycles of the AC power frequency.[3]
Operation of CB

• All circuit breaker systems 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 itself. Circuit breakers for large-currents or high-voltages are usually arranged with protective relay pilot devices to sense a fault condition 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, protective relays, and an internal control power source.
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Once a fault is detected, the contacts within the circuit breaker must immediately open to interrupt the current; some mechanically-stored energy (using something such as springs or compressed air) contained within the breaker is used to quickly separate the contacts, although some of the energy required may be obtained from the immense heating effect of the fault current itself. 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 (opening) the circuit.
CB contacts are made of copper or copper alloys, silver alloys, and other highly conductive materials. Service life of the contacts is limited by the erosion of contact material due to arcing while interrupting the current. Miniature and molded-case circuit breakers are usually discarded when the contacts have worn, but power circuit breakers and high-voltage circuit breakers have replaceable contacts.

When a fault 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 withstand the voltage in the circuit. Different circuit breakers use vacuum, air, insulating gas or oil as the medium the arc forms in. Different techniques are used to effectively extinguish the arc including the following ways:
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1. Arc-lengthening (deflection of the arc)
2. Intensive cooling (in jet chambers)
3. Division into partial arcs
4. Zero point quenching (Contacts open at the zero current time crossing of the AC waveform, effectively breaking no load current at the time of opening. The zero crossing occurs at twice the line frequency, i.e. 100 times per second for 50 Hz and 120 times per second for 60 Hz AC)
5. Connecting charge-capacitors in parallel with contacts in DC circuits.

Finally, once the fault condition has been cleared, the contacts must again be reclosed to restore power to the interrupted circuits.
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Arc interruption

• Low-voltage Miniature Circuit Breakers (MCB) uses air alone to extinguish the arc. Larger ratings have metal plates and non-metallic arc chutes to divide and cool the arc. Magnetic blowout coils or permanent magnets 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-vapor through the arc.[4]

• Gas (usually Sulfur-Hexafluoride, SF$_6$) circuit breakers sometimes stretch the arc using the magnetic field, and then rely upon the dielectric strength of the Sulfur-Hexafluoride gas (SF$_6$) to quench and extinguish the stretched arc.
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• 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 (less than 2–3 mm (0.079–0.118 in)). Vacuum circuit breakers are frequently used in modern medium-voltage switchgear to 38,000 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.
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**Short-circuit current**

- Circuit breakers are rated both by the normal load-current that they are expected to carry without overheating, and the maximum short-circuit current that they can safely interrupt.

- Under short-circuit conditions, the calculated maximum prospective short circuit current may be many times the normal, rated load current of the circuit. When electrical contacts open to interrupt a large fault current, there is a tendency for an arc to form between the opened contacts, which would allow the current to continue. This condition can create conductive ionized gases and molten or vaporized metal, which can cause further continuation of the arc, or creation of additional short circuits, potentially resulting in the **explosion** of the circuit breaker and the equipment that it is installed in. Therefore, circuit breakers must incorporate various features to divide and extinguish the arc.
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- 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 sulfur hexafluoride or have 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, but only to explode when reset.

- MCB used to protect control circuits or small appliances may not have sufficient interrupting capacity to be used at a panel board; these circuit breakers are called "supplemental circuit protectors" to distinguish them from distribution-type circuit breakers.
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Standard current ratings

• Circuit breakers are manufactured in standard sizes, using a system of preferred numbers to cover a range of ratings. Miniature circuit breakers MCB have a fixed trip-setting; changing the operating current value requires changing the whole circuit breaker.

• Larger circuit breakers can have adjustable trip-settings, allowing standardized elements to be applied but with a setting intended to improve protection. For example, a circuit breaker with a 400 ampere "frame size" might have its overcurrent detection set to operate at only 300 amperes, to protect a feeder cable.
International Standards--- IEC 60898-1 and European Standard EN 60898-1 define the rated current of a circuit breaker for low-voltage distribution applications as the maximum 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 currents are: 6 A, 10 A, 13 A, 16 A, 20 A, 25 A, 32 A, 40 A, 50 A, 63 A, 80 A, 100 A,[5] and 125 A (Renard series, are slightly modified to include current limit of British BS 1363 sockets).

The circuit breaker is labeled with the rated normal load-current in amperes, but without the unit symbol "A". Instead, the normal ampere value figure is preceded by a letter "B", "C" or "D", which indicates the instantaneous tripping current value — 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). The letters "B", "C" or "D", ... mean:
<table>
<thead>
<tr>
<th>Type</th>
<th>Instantaneous tripping current</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>above $3 \ I_n$ up to and including $5 \ I_n$</td>
</tr>
<tr>
<td>C</td>
<td>above $5 \ I_n$ up to and including $10 \ I_n$</td>
</tr>
<tr>
<td>D</td>
<td>above $10 \ I_n$ up to and including $20 \ I_n$</td>
</tr>
<tr>
<td>K</td>
<td>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.</td>
</tr>
<tr>
<td>Z</td>
<td>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.</td>
</tr>
</tbody>
</table>
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• Circuit breakers are also rated by the maximum fault current that they can interrupt; this allows use of more economical devices on systems unlikely to develop the high short-circuit current found on, for example, a large commercial building distribution system.

• In the United States, Underwriters Laboratories (UL) certifies equipment ratings, called **Series Ratings** (or “integrated equipment ratings”) for circuit breaker equipment used for **buildings**.

• Power circuit breakers and medium- and high-voltage circuit breakers used for industrial or electric power systems are designed and tested to ANSI/IEEE standards in the C37 series.
Types of circuit breakers
Many different classifications of circuit breakers can be made, based on their features such as voltage class, construction type, interrupting type, and structural features.

1. Low-voltage circuit breakers
Low-voltage (less than 1,000 V_{AC}) types are common in domestic, commercial and industrial applications, and 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.
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Four one-pole miniature circuit breakers

A two-pole miniature circuit breakers
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An air circuit breaker for low-voltage (less than 1,000 volt) power distribution switchgear
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There are three main types of MCBs: 1. Type B - trips between 3 and 5 times full load current; 2. Type C - trips between 5 and 10 times full load current; 3. Type D - trips between 10 and 20 times full load current. In the UK all MCBs must be selected in accordance with BS 7671 standard.

MCCB (Molded Case Circuit Breaker)—normal rated current is up to 2,500 A with thermal or thermal-magnetic operation. Trip current may be adjustable in larger ratings.

Low-voltage power circuit breakers (i.e., it carries high-current) can be mounted in multi-tiers in low-voltage switchboards or switchgear cabinets.
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Molded-case circuit breaker MCCB
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• The characteristics of low-voltage 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 electric motor operators so they can open and close under remote control. These may form a part of an automatic transfer switch system for standby power.
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• Low-voltage circuit breakers are also made for direct-current (DC) applications, such as DC for subway lines. Direct current requires special breakers because the arc is continuous (i.e., no zero-crossing positions)—unlike an AC arc, which tends to cross out on each half cycle of the sine-waveform.

• A direct current circuit breaker has blow-out coils that generate a magnetic field that rapidly stretches or lengthens the arc to be extinct. Small circuit breakers are either installed directly in the equipment, or are arranged in a breaker panel (i.e., switch-board or switch-gear).
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- The DIN, rail-mounted, thermal-magnetic miniature circuit breaker MCB is the most common style in modern domestic consumer units and commercial electrical distribution boards throughout Europe.

The construction of this 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 of these types 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** - for wires connection
5. **Thermal Bimetallic strip** - separates contacts in response to smaller, longer-term overcurrents (i.e., over load currents)
6. **Calibration screw** - allows the manufacturer to precisely adjust the trip current of the device after assembly.
7. **Magnetic Solenoid** - separates the contacts rapidly in response to high overcurrents from faults (i.e., short circuit currents).
8. **Arc divider/extinguisher** – to cool the arc
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Inside construction of a circuit breaker
2. Magnetic circuit breakers

- Magnetic circuit breakers use a solenoid (electromagnet) whose pulling force increases with the (load) current. Certain designs utilize more electromagnetic forces in addition to those of the solenoid. 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 lets the contacts open by a spring action.

- Some magnetic circuit breakers incorporate a hydraulic time delay feature using a viscous fluid. A spring restrains the core until the current exceeds the breaker rating. During an overload, the speed of the solenoid motion is restricted by the viscous fluid.
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- The delay feature of the these circuit breakers permits brief current surges beyond normal running current for motor starting, energizing equipment, etc.
- Short circuit currents provide sufficient solenoid magnetic force to release the latch regardless of core position thus bypassing the delay feature.
- Ambient temperature affects the time delay feature of these circuit breakers but does not affect the current rating of the magnetic feature.
3. Thermal magnetic circuit breakers

- *Thermal magnetic 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 overcurrent conditions.

- The thermal portion of the circuit breaker provides an "inverse time" response feature, which trips the circuit breaker sooner for larger overcurrents but allows smaller overloads to persist for a longer time.

- On large over-currents or during short-circuit faults, the magnetic element is the first to trip the circuit breaker before the thermal element with no intentional additional time delay.[6]
4. Common trip breakers (gang-operated)

When supplying a branch circuit load 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 enclosure (one mechanism for each conductor) as an independent system, or for small breakers, may externally tie the poles together via their operating handles (actuators).

- **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.
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Two-pole, externally tied, common trip MCB
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Three-pole common trip MCCB

Three-pole, externally tied, common trip MCB
Two- and four-pole breakers are used when there is a need to disconnect multiple phase AC, or to disconnect the neutral wire to ensure that no current flows through the neutral wire from other loads connected to the same network when or where workers may touch the wires during maintenance. Here, the two-pole breaker is used for single-phase circuits, whereas the four-pole breaker is used for three-phase circuits.

Separate circuit breakers must never be used for live and neutral conductors alone, because if the neutral is disconnected while the live conductors stay connected, a dangerous condition arises; the wires remain live and some RCD (Residual Current Devices) circuit breakers may not trip if someone touches the live wire (because some RCDs need power to trip). This is why only common trip circuit breakers must be used when neutral wire switching is needed.
5. 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 40.5 kV). Like the high voltage circuit breakers described later, 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 protective relays, instead of relying on built-in thermal or magnetic overcurrent sensors.
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Medium-voltage circuit breakers can also be classified by the medium used to extinguish the arc as:

• Vacuum circuit breakers—With rated current up to 6,300 A, and higher for generator circuit breakers. These breakers interrupt the current by creating and extinguishing the arc in a vacuum container "bottle".

Long life bellows are designed to travel the 6-10 mm the contacts must part. These are generally applied for voltages up to about 40,500 V,\textsuperscript{[7]} 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.
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• Air circuit breakers—Rated current up to 6,300 A and higher for generator circuit breakers. 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 breaker removal without disturbing power circuit connections, using a motor-operated or hand-cranked mechanism to separate the breaker from its enclosure.

• Some important manufacturer of VCB from 3.3 kV to 38 kV are Eaton, ABB, Siemens, HHI (Hyundai Heavy Industry), S&C Electric Company, Jyoti and BHEL.
6. 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 72.5 kV 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 protective relay scheme can be complex, protecting equipment and buses from various types of overload or ground/earth fault.
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High-voltage circuit breakers are broadly classified by the medium used to extinguish the arc:

1. Bulk oil
2. Minimum oil
3. Air blast
4. Vacuum
5. SF$_6$
6. CO$_2$
Some of the manufacturers are ABB, Alstom, General Electric, Hitachi, HYOSUNG (HICO), Hyundai Heavy Industry (HHI), Mitsubishi Electric, Pennsylvania Breaker, Siemens, Toshiba, Končar HVS, BHEL, CGL, and Becker/SMC (SMC Electrical Products).

Due to environmental and cost concerns over insulating oil spills, most new breakers use SF6 gas to quench the arc.

Circuit breakers 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 kV. 1,200 kV breakers were launched by Siemens in November 2011,[8] followed by ABB in April the following year.[9]
• 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, reliability and availability.

• A high-voltage direct current circuit breaker uses DC transmission lines rather than the AC transmission lines that dominate as of 2013. An HVDC circuit breaker can be used to connect DC transmission lines into a DC transmission grid, thereby making it possible to link renewable energy sources and even out local variations in wind and solar power.[10]
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Three single phase 110 kV oil circuit breakers
7. Sulfur hexafluoride (SF$_6$) high-voltage circuit breakers

- High-voltage circuit breakers have greatly changed since they were first introduced in the mid-1950s, 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 (bushings) mounted on a structure.

- Current interruption in a high-voltage circuit-breaker is obtained by separating two contacts in a medium, such as sulfur hexafluoride (SF$_6$), 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.
A gas blast applied to 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 (TRV) that is applied across the contacts after current interruption. Sulfur hexafluoride is generally used in present high-voltage circuit-breakers at rated voltage higher than 52 kV.

Into the 1980s, the pressure necessary to blast the arc was generated mostly by gas heating using arc energy. Therefore, it is now possible to use low energy spring-loaded mechanisms to drive high-voltage circuit-breakers up to 800 kV in assisted puffer CB.
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Brief history of SF$_6$ breakers

- The first patents on the use of SF$_6$ as an interrupting medium were filed in Germany in 1938 by Vitaly Grosse (AEG) and independently later in the United States in July 1951 by H. J. Lingal, T. E. Browne and A. P. Storm (Westinghouse).

- The first industrial application of SF$_6$ for current interruption dates to 1953. High-voltage 15 kV to 161 kV load switches were developed with a breaking capacity of 600 A. The first high-voltage SF$_6$ circuit-breaker built in 1956 by Westinghouse, could interrupt 5 kA under 115 kV, but it had **six interrupting chambers in series per pole**.

- In 1957, the puffer-type technique was introduced for SF$_6$ circuit breakers, wherein 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 (upcoming Figure). In this technique, the pressure rise is obtained mainly by gas compression.
The first high-voltage SF$_6$ 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 was 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 SF$_6$ 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.

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The achievement around 1983 of the first single-break 245 kV and the corresponding 420 kV 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 breaking time of 2 to 2.5 cycles
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• High electrical endurance, allowing at least 25 years of operation without reconditioning;
• Possible compact solutions when used for gas insulated switchgear 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 International Council on Large Electric Systems (CIGRE) surveys.
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Gas circuit breaker operation
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400 kV SF₆ live tank circuit breakers
8. Disconnecting circuit breaker (DCB)

- The disconnecting circuit breaker (DCB) was introduced in the year 2000[11] and is a high-voltage circuit breaker modeled after the SF6-breaker. It presents a technical solution where the disconnecting function is integrated in the breaking chamber, eliminating the need for separate disconnectors. This increases the availability, since open-air disconnecting switch main contacts need maintenance every 2–6 years, while modern circuit breakers have maintenance intervals of 15 years.

- Implementing a DCB solution also reduces the space requirements within the substation, and increases the reliability, due to the elimination of separate disconnectors.[12][13]
In order to further reduce the required space of substation, as well as simplifying the design and engineering of the substation, a fiber optic current sensor (FOCS) can be integrated with the DCB. A 420 kV DCB with integrated FOCS can reduce a substation’s footprint with over 50% compared to a conventional solution of live tank breakers with disconnectors and current transformers, due to reduced material and no additional insulation medium.[14]
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72.5 kV Hybrid Switchgear Module
9. Carbon dioxide (CO₂) high-voltage circuit breakers

• In 2012 ABB presented a 75 kV high-voltage breaker that uses carbon dioxide as the medium to extinguish the arc. The carbon dioxide breaker works on the same principles as an SF₆ breaker and can also be produced as a disconnecting circuit breaker.

• By switching from SF₆ to CO₂ it is possible to reduce the CO₂ emissions by 10 tons during the product’s life cycle due to usage.\(^{[15]}\)
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72.5 kV carbon dioxide high-voltage circuit breaker
10. Other types of circuit breakers
The following are other types of circuit breakers:

• 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.
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• 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 Interrupter (GFI) breakers; a wall mounted outlet device or separately enclosed plug-in device providing ground fault detection and interruption only (no overload protection) is called a Ground Fault Circuit Interrupter (GFCI).
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• 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.

• Recloser—a type of circuit breaker that closes automatically after a delay. These are used on overhead electric 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.
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**Circuit breaker electronic symbols**

- Circuit Breaker (Utility, Drawout)
- Circuit Breaker (Utility, Non-Drawout)
- Molded Case Circuit Breaker (Industry, Drawout)
- Molded Case Circuit Breaker (Industry, Non-Drawout)
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• References


