**Circuit Breaker**

A **circuit breaker** is an automatically operated [electrical](http://en.wikipedia.org/wiki/Electricity) [switch](http://en.wikipedia.org/wiki/Switch) designed to protect an [electrical circuit](http://en.wikipedia.org/wiki/Electrical_network) from damage caused by [overload](http://en.wikipedia.org/wiki/Overcurrent) or [short circuit](http://en.wikipedia.org/wiki/Short_circuit). Its basic function is to detect a fault condition and, by interrupting continuity, to immediately discontinue electrical flow. Unlike a [fuse](http://en.wikipedia.org/wiki/Fuse_(electrical)), 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](http://en.wikipedia.org/wiki/Switchgear) designed to protect high voltage circuits feeding an entire city.

Other Breakers

* Breakers for protections against earth faults too small to trip an over-current device:
  + [Residual-current device](http://en.wikipedia.org/wiki/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](http://en.wikipedia.org/wiki/Residual-current_device) (RCBO) — combines the functions of an RCD and an MCB in one package. In the [United States](http://en.wikipedia.org/wiki/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](http://en.wikipedia.org/wiki/ELCB) (ELCB) — This detects earth current directly rather than detecting imbalance. They are no longer seen in new installations for various reasons.
* [Autorecloser](http://en.wikipedia.org/wiki/Autorecloser) — A type of circuit breaker which closes again after a delay. These are used on overhead [power distribution](http://en.wikipedia.org/wiki/Power_distribution) systems, to prevent short duration faults from causing sustained outages.
* [Polyswitch](http://en.wikipedia.org/wiki/Polyswitch) (polyfuse) — A small device commonly described as an automatically resetting fuse rather than a circuit breaker.

**Types of circuit breaker**

[](http://en.wikipedia.org/wiki/File:LargeCircuitBreaker.jpg)

[http://bits.wikimedia.org/skins-1.17/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:LargeCircuitBreaker.jpg)

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](http://en.wikipedia.org/wiki/DIP_switch) on the front panel.

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 VAC) types are common in domestic, commercial and industrial application, and include:

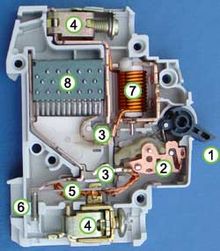
* MCB (Miniature Circuit Breaker)—rated current not more than 100 A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category.
* MCCB (Molded Case Circuit Breaker)—rated current up to 2500 A. Thermal or thermal-magnetic operation. Trip current may be adjustable in larger ratings.
* Low voltage power circuit breakers can be mounted in multi-tiers in LV switchboards or [switchgear](http://en.wikipedia.org/wiki/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](http://en.wikipedia.org/wiki/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](http://en.wikipedia.org/wiki/Circuit_breaker_panel).

[](http://en.wikipedia.org/wiki/File:Circuitbreaker.jpg)

[http://bits.wikimedia.org/skins-1.17/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Circuitbreaker.jpg)

Photo of inside of a circuit breaker

The 10 ampere [DIN rail](http://en.wikipedia.org/wiki/DIN_rail)-mounted thermal-magnetic miniature circuit breaker is the most common style in modern domestic [consumer units](http://en.wikipedia.org/wiki/Consumer_unit) and commercial electrical [distribution boards](http://en.wikipedia.org/wiki/Distribution_board) throughout [Europe](http://en.wikipedia.org/wiki/Europe). The design includes the following components:

1. Actuator [lever](http://en.wikipedia.org/wiki/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](http://en.wikipedia.org/wiki/Screw) - allows the [manufacturer](http://en.wikipedia.org/wiki/Manufacturer) to precisely adjust the trip current of the device after assembly.
7. Solenoid
8. Arc divider/extinguisher

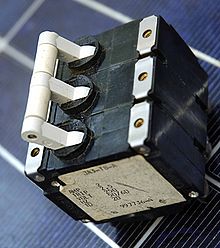
**Magnetic circuit breaker**

*Magnetic circuit breakers* use a [solenoid](http://en.wikipedia.org/wiki/Solenoid) ([electromagnet](http://en.wikipedia.org/wiki/Electromagnet)) whose pulling force increases with the [current](http://en.wikipedia.org/wiki/Current_(electricity)). Certain designs utilize 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 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.

**Thermal magnetic circuit breaker**

*Thermal magnetic circuit breakers*, which are the type found in most [distribution boards](http://en.wikipedia.org/wiki/Distribution_board), 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.

**Common trip breakers**

[](http://en.wikipedia.org/wiki/File:Breaker3phase2a_proc.jpg)

[http://bits.wikimedia.org/skins-1.17/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Breaker3phase2a_proc.jpg)

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

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](http://en.wikipedia.org/wiki/Major_appliance) or further distribution boards) span the two live wires. Three-pole common trip breakers are typically used to supply [three-phase electric power](http://en.wikipedia.org/wiki/Three-phase_electric_power) to large motors or further distribution boards.

Two and four pole breakers are used when there is a need to disconnect the neutral wire, to be sure that no current can flow back through the neutral wire from other loads connected to the same network when people need to touch the wires for maintenance. Separate circuit breakers must never be used for disconnecting live and neutral, because if the neutral gets disconnected while the live conductor stays connected, a dangerous condition arises: the circuit will appear de-energized (appliances will not work), but wires will stay live and [RCDs](http://en.wikipedia.org/wiki/Residual-current_device) will not trip if someone touches the live wire (because RCDs need power to trip). This is why only common trip breakers must be used when switching of the neutral wire is needed.

**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](http://en.wikipedia.org/wiki/Electrical_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](http://en.wikipedia.org/wiki/Relay) operated through [current transformers](http://en.wikipedia.org/wiki/Current_transformer). 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](http://en.wikipedia.org/wiki/Protective_relay), 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 are generally applied for voltages up to about 35,000 V,[[4]](http://en.wikipedia.org/wiki/Circuit_breaker" \l "cite_note-3) 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](http://en.wikipedia.org/wiki/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**

*Main article:* [*High-voltage switchgear*](http://en.wikipedia.org/wiki/High-voltage_switchgear)

[](http://en.wikipedia.org/wiki/File:Oil_circuit_breaker_MKP-110_Toliatti_Russia.jpg)

[http://bits.wikimedia.org/skins-1.17/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Oil_circuit_breaker_MKP-110_Toliatti_Russia.jpg)

Russian 110 kV oil circuit breaker

[](http://en.wikipedia.org/wiki/File:115kV_Oil_Circuit_Breaker.JPG)

[http://bits.wikimedia.org/skins-1.17/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:115kV_Oil_Circuit_Breaker.JPG)

115 kV bulk oil circuit breaker

[](http://en.wikipedia.org/wiki/File:400kv.jpg)

[http://bits.wikimedia.org/skins-1.17/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:400kv.jpg)

400 kV SF6 live tank circuit breakers

Electrical [power transmission](http://en.wikipedia.org/wiki/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](http://en.wikipedia.org/wiki/International_Electrotechnical_Commission) (IEC). High-voltage breakers are nearly always [solenoid](http://en.wikipedia.org/wiki/Solenoid)-operated, with current sensing [protective relays](http://en.wikipedia.org/wiki/Protective_relay) operated through [current transformers](http://en.wikipedia.org/wiki/Current_transformer). In [substations](http://en.wikipedia.org/wiki/Electrical_substation) the protective relay scheme can be complex, protecting equipment and buses 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
* Vacuum
* [SF6](http://en.wikipedia.org/wiki/Sulfur_hexafluoride)

Some of the manufacturers are [ABB](http://en.wikipedia.org/wiki/ABB_Group), [GE (General Electric)](http://en.wikipedia.org/wiki/General_electric) , [Tavrida Electric](http://en.wikipedia.org/w/index.php?title=Tavrida_Electric&action=edit&redlink=1), [Alstom](http://en.wikipedia.org/wiki/Alstom), Mitsubishi Electric, Pennsylvania Breaker, [Siemens](http://en.wikipedia.org/wiki/Siemens), [Toshiba](http://en.wikipedia.org/wiki/Toshiba), Končar HVS, BHEL, CGL, Square D (Schneider Electric).

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. 1200KV breakers are likely to come into market very soon.

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**

*Main article:* [*Sulfur hexafluoride circuit breaker*](http://en.wikipedia.org/wiki/Sulfur_hexafluoride_circuit_breaker)

A sulfur hexafluoride circuit breaker uses contacts surrounded by sulfur hexafluoride gas to quench the arc. They are most often used for transmission-level voltages and may be incorporated into compact gas-insulated switchgear. In cold climates, supplemental heating or de-rating of the circuit breakers may be required due to liquefaction of the SF6 gas.

**IEC STANDARDS:**

* [IEC 60027](http://en.wikipedia.org/wiki/IEC_60027) Letter symbols to be used in electrical technology...
* IEC 60034 Rotating electrical machinery
* [IEC 60038](http://en.wikipedia.org/wiki/IEC_60038) IEC Standard Voltages
* IEC 60044 Instrument transformers
* IEC 60050 [International Electrotechnical Vocabulary](http://std.iec.ch/iec60050)
* [IEC 60062](http://en.wikipedia.org/wiki/Electronic_color_code) Marking codes for resistors and capacitors
* [IEC 60063](http://en.wikipedia.org/wiki/Preferred_number#E_series:_Capacitors_and_resistors) [Preferred number](http://en.wikipedia.org/wiki/Preferred_number) series for resistors and capacitors
* IEC 60065 Audio, video and similar electronic apparatus - Safety requirements
* IEC 60068 Environmental Testing
* IEC 60071 Insulation Co-ordination
* IEC 60073 Basic Safety principles for man-machine interface, marking and identification
* IEC 60076 Power [Transformers](http://en.wikipedia.org/wiki/Transformer)
* IEC 60079 Parts 1-14 [Electrical Installations in Hazardous Areas](http://en.wikipedia.org/wiki/Electrical_equipment_in_hazardous_areas)
* IEC 60085 Electrical insulation
* IEC 60086 Primary [batteries](http://en.wikipedia.org/wiki/Battery_(electricity))
* IEC 60094 Magnetic tape sound recording and reproducing systems
* IEC 60096 Radio-frequency cables
* IEC 60098 Rumble measurement on Vinyl Disc Turntables
* IEC 60099 Surge arresters
* IEC 60134 Absolute maximum and design ratings of tube and semiconductor devices
* IEC 60137 Bushings for alternating voltages above 1000V
* IEC 60146 Semiconductor Converters
* IEC 60169 Radio-frequency connectors
* IEC 60183 Guide to the selection of high voltage cables
* IEC 60204 Safety of machinery
* IEC 60214 On-load tap changers
* [IEC 60228](http://en.wikipedia.org/wiki/IEC_60228) Conductors of insulated cables
* IEC 60233 Tests on Hollow Insulators for use in Electrical Equipment
* IEC 60238 Edison screw lampholders
* IEC 60245 Rubber-Insulated Cables
* IEC 60255 Electrical Relays
* IEC 60268 Sound system equipment
* IEC 60269 Low voltage fuses
* IEC 60270 High-Voltage Test Techniques - Partial Discharge Measurements
* IEC 60287 Calculation of permissible current in cables at steady state rating
* IEC 60092-350 Shipboard Power cables-General construction and Test Requirements
* IEC 60296 Mineral Insulating oils for transformers & switchgear
* IEC 60297 [19-inch rack](http://en.wikipedia.org/wiki/19-inch_rack)
* IEC 60298 high voltage switchgear in metallic enclosure
* [IEC 60309](http://en.wikipedia.org/wiki/IEC_60309) Plugs, socket-outlets and couplers for industrial purposes
* IEC 60317 Specifications for particular types of winding wires
* [IEC 60320](http://en.wikipedia.org/wiki/IEC_connector) Appliance couplers for household and similar general purposes ([IEC connector](http://en.wikipedia.org/wiki/IEC_connector))
* IEC 60331 Tests for Electric Cables under Fire Conditions
* [IEC 60335](http://en.wikipedia.org/w/index.php?title=IEC_60335&action=edit&redlink=1) Safety of electrical household appliances
* [IEC 60364](http://en.wikipedia.org/wiki/IEC_60364) Electrical installations of buildings
* IEC 60417 Graphical symbols for use on equipment
* IEC 60439 Low voltage switchgear and controlgear assemblies
* IEC 60445 Basic and safety principles for man-machine interface
* IEC 60446 Wiring colours
* IEC 60479 Effects of current on human beings and livestock
* IEC 60502 Power cables with extruded insulation and their accessories for rated voltages from 1KV up to 30KV
* IEC 60529 Degrees of protection provided by enclosures (IP Code)
* IEC 60571 Electronic equipment used on rail vehicles
* IEC 60574 Audio-visual, video and television equipment and systems
* IEC 60598 Luminaires
* IEC 60559 Binary floating-point arithmetic for microprocessor systems (equivalent to [IEEE 754-1989](http://en.wikipedia.org/wiki/IEEE_754))
* [IEC 60601](http://en.wikipedia.org/wiki/IEC_60601-1) Medical Electrical Equipment
* IEC 60603 Connectors for frequencies below 3 MHz for use with printed boards
* IEC 60617 Graphical symbols for diagrams
* IEC 60651 Sound level meters (status is withdrawn)
* IEC 60694 High-voltage switchgear and control gear standards
* IEC 60715 Dimensions of low-voltage switchgear and controlgear. Standardised mounting on rails for mechanical support of electrical devices in switchgear and controlgear installations.
* IEC 60721 Classification of environmental conditions
* IEC 60726 Dry type power transformers
* IEC 60747 Semiconductor devices; Part 1: General
* IEC 60748 Semiconductor devices - integrated circuits
* IEC 60774 [VHS](http://en.wikipedia.org/wiki/VHS)/[S-VHS](http://en.wikipedia.org/wiki/S-VHS) video tape cassette system
* IEC 60793 [Optical fibres](http://en.wikipedia.org/wiki/Optical_fibre)
* IEC 60812 International Standard on Fault Mode and Effects Analysis
* IEC 60815 Selection and dimensioning of high-voltage insulators intended for use in polluted conditions
* IEC 60825 [Laser safety](http://en.wikipedia.org/wiki/Laser_safety)
* IEC 60849 Sound Systems for Emergency Purposes
* IEC 60870 Telecontrol equipment and systems
* IEC 60874 Connectors for optical fibres
* IEC 60884 Plugs and socket-outlets for household and similar purposes
* IEC 60898 Electrical accessories. [Circuit breakers](http://en.wikipedia.org/wiki/Circuit_breaker) for overcurrent protection for household and similar installations.
* IEC 60906 IEC system of plugs and socket-outlets for household and similar purposes
* [IEC 60908](http://en.wikipedia.org/wiki/Red_Book_(audio_CD_standard)) [Compact disk](http://en.wikipedia.org/wiki/Compact_disk) digital audio system
* IEC 60921 [Ballasts](http://en.wikipedia.org/wiki/Electrical_ballast) for tubular [fluorescent lamps](http://en.wikipedia.org/wiki/Fluorescent_lamp) - Performance requirements
* [IEC 60929](http://en.wikipedia.org/wiki/IEC_60929) AC-supplied electronic [ballasts](http://en.wikipedia.org/wiki/Electrical_ballast) for tubular [fluorescent lamps](http://en.wikipedia.org/wiki/Fluorescent_lamp) - Performance requirements
* IEC 60942 Electroacoustics - Sound calibrators
* IEC 60945 Maritime Navigation and Radiocommunication Equipment and Systems - General Requirements - Methods of Testing and Required Test Results
* IEC 60947 Standards for low-voltage switchgear and controlgear
* IEC 60950 Safety of information technology equipment
* IEC 61000 Electromagnetic compatibility (EMC)
* IEC 61009 Residual current operated circuit breakers with integral overcurrent protection for household and similar uses (RCBO's)
* IEC 61010 Safety requirements for electrical equipment for measurement, control and laboratory use
* IEC 61025 [Fault tree analysis](http://en.wikipedia.org/wiki/Fault_tree_analysis)
* IEC 61043 [Sound intensity](http://en.wikipedia.org/wiki/Sound_intensity) meters with pairs of microphones
* IEC 61058 [Switches](http://en.wikipedia.org/wiki/Switch) for Appliances
* IEC 61097 Global maritime distress and safety system (GMDSS)
* [IEC 61131](http://en.wikipedia.org/wiki/IEC_61131) [PLC](http://en.wikipedia.org/wiki/Programmable_Logic_Controller) programming.
* IEC 61149 Safety of mobile radios
* IEC 61156 Multicore and symmetrical pair/qud cables for digital communications
* [IEC 61158](http://en.wikipedia.org/wiki/Fieldbus) Industrial communication networks - Fieldbus specifications
* IEC 61162 Maritime navigation and radiocommunication equipment and systems
* IEC 61164 Reliability growth – Statistical test and estimation methods
* IEC 61215, Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval
* IEC 61238, Compression and mechanical connectors for power cables for rated voltages up to 30 kV
* IEC 61277, Terrestrial photovoltaic (PV) power generating systems - General and guide
* IEC 61280 Field testing method for measuring single mode fibre optic cable
* IEC 61286 Character set with electrotechnical symbols (ISO-IR 181 [[1]](http://www.itscj.ipsj.or.jp/ISO-IR/181.pdf))
* IEC 61326 Electrical equipment for measurement, control and laboratory use - EMC requirements
* IEC 61345, UV test for photovoltaic (PV) modules
* [IEC 61346](http://en.wikipedia.org/wiki/IEC_61346) Industrial systems, installations and equipment and industrial products — Structuring principles and reference designations
* [IEC 61355](http://en.wikipedia.org/wiki/IEC_61355) Classification and designation of documents for plants, systems and equipment
* IEC 61378 Converter Transformers
* IEC 61400 [Wind turbines](http://en.wikipedia.org/wiki/Wind_turbine)
* IEC 61439 Low-Voltage switchgear and control gear assemblies
* [IEC 61499](http://en.wikipedia.org/wiki/IEC_61499) Function blocks
* [IEC 61508](http://en.wikipedia.org/wiki/IEC_61508) Functional safety of electrical/electronic/programmable electronic safety-related systems
* [IEC 61511](http://en.wikipedia.org/wiki/IEC_61511) Functional safety - safety instrumented systems for the process industry sector
* IEC 61537 Cable management - Cable tray systems and cable ladder systems
* IEC 61557 Equipment for measuring electrical safety in low-voltage distribution systems
* [IEC 61588](http://en.wikipedia.org/wiki/Precision_Time_Protocol) Precision clock synchronization protocol for networked measurement and control systems
* IEC 61603 Infrared transmission of audio or video signals
* IEC 61672 Electroacoustics – Sound level meters(61672-1 and 61672-1 cancels and replaces IEC 60651, Sound level meters, and IEC 60804, Integrating-averaging sound level meters)
* IEC 61643 Surge protective devices connected to low-voltage power distribution systems
* IEC 61646, Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval
* [IEC 61690](http://en.wikipedia.org/wiki/IEC_61690) Electronic design interchange format, [EDIF](http://en.wikipedia.org/wiki/EDIF)
* IEC 61701, Salt mist corrosion testing of photovoltaic (PV) modules
* IEC 61784 Industrial communication networks - Profiles
* IEC 61730 [Photovoltaic modules](http://en.wikipedia.org/wiki/Solar_panel)
* IEC 61800 Adjustable speed electrical power drive systems
* IEC 61829, Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics
* [IEC 61850](http://en.wikipedia.org/wiki/IEC61850) Communication Networks and Systems in Substations
* IEC 61892, Part 1 and 2, Mobile and fixed offshore units, electrical installations
* IEC 61966 Multimedia systems -- [Colour](http://en.wikipedia.org/wiki/Colour) measurement
* [IEC 61968](http://en.wikipedia.org/wiki/IEC_61968) Application integration at electric utilities – System interfaces for distribution management
* [IEC 61970](http://en.wikipedia.org/wiki/IEC_61970) Application integration at electric utilities – Energy management system application program interface (EMS-API)
* IEC 61993 Maritime navigation and radio communication equipment and systems.
* IEC 62040 Uninterruptible power systems
* [IEC 62056](http://en.wikipedia.org/wiki/IEC_62056) DLM/COSEM communication protocol for reading utility meters
* IEC 62087 Methods of measurement for the power consumption of audio, video and related equipment
* IEC 62108, Concentrator photovoltaic (CPV) modules and assemblies - Design qualification and type approval
* [IEC 62196](http://en.wikipedia.org/wiki/IEC_62196) Plugs and sockets for charging [electric vehicles](http://en.wikipedia.org/wiki/Electric_vehicle)
* [IEC 62264](http://en.wikipedia.org/wiki/IEC_62264) Enterprise-control system integration
* IEC 62262 Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
* IEC 62270 Hydroelectric power plant automation - Guide for computer-based control
* IEC 62271 Standards for high-voltage switchgear and controlgear
* IEC 62278 Railway applications – Specification and demonstration of reliability, availability, maintainability and safety (RAMS)
* IEC 62282 Fuel cell technologies
* IEC 62301 Household electrical appliances - Measurement of standby power
* [IEC 62304](http://en.wikipedia.org/wiki/IEC_62304) Medical Device Software - Software Life Cycle Processes
* IEC 62325 Standards related to energy market models & communications
* [IEC 62351](http://en.wikipedia.org/wiki/IEC_62351) Power System Control and Associated Communications - Data and Communication Security
* IEC 62366 Medical devices—Application of usability engineering to medical devices
* [IEC 62379](http://en.wikipedia.org/wiki/IEC_62379) Common control interface for networked digital audio and video products
* IEC 62443 Industrial communication networks - Network and system security (DRAFT)
* IEC 62455 Internet protocol (IP) and transport stream (TS) based service access
* IEC 62464 Magnetic resonance equipment for medical imaging
* IEC 62471 Photobiological safety of lamps and lamp systems
* IEC 62481 Digital living network alliance (DLNA) home networked device interoperability guidelines - Part 1: Architecture and protocols
* IEC 62502 Analysis techniques for dependability – Event tree analysis (ETA)

**High Voltage:**

The term **high voltage** characterizes electrical circuits in which the voltage used is the cause of particular safety concerns and insulation requirements. High voltage is used in [electrical power distribution](http://en.wikipedia.org/wiki/Electrical_power_distribution), in [cathode ray tubes](http://en.wikipedia.org/wiki/Cathode_ray_tube), to generate [X-rays](http://en.wikipedia.org/wiki/X-rays) and [particle beams](http://en.wikipedia.org/wiki/Particle_beam), to demonstrate [arcing](http://en.wikipedia.org/wiki/Arcing), for ignition, in [photomultiplier tubes](http://en.wikipedia.org/wiki/Photomultiplier), and in high power [amplifier](http://en.wikipedia.org/wiki/Amplifier) [vacuum tubes](http://en.wikipedia.org/wiki/Vacuum_tube) and other industrial and scientific applications.

Safety:

Voltages of greater than 50 V applied across dry unbroken human skin are capable of producing heart [fibrillation](http://en.wikipedia.org/wiki/Fibrillation) if they produce [electric currents](http://en.wikipedia.org/wiki/Electric_current) in body tissues that happen to pass through the [chest](http://en.wikipedia.org/wiki/Chest) area.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] The [electrocution](http://en.wikipedia.org/wiki/Electric_shock) danger is mostly determined by the low [electrical conductivity](http://en.wikipedia.org/wiki/Electrical_conductivity) of dry human skin. If skin is wet, or if there are wounds, or if the voltage is applied to [electrodes](http://en.wikipedia.org/wiki/Electrode) that penetrate the skin, then even voltage sources below 40 V can be lethal if contacted.

Accidental contact with high voltage supplying sufficient energy will usually result in severe injury or death. This can occur as a person's body provides a path for current flow, causing tissue damage and heart failure. Other injuries can include burns from the arc generated by the accidental contact. These can be especially dangerous if the victim's airways are affected. Injuries may also be suffered as a result of the physical forces exerted as people may fall from height or be thrown a considerable distance.

Low-energy exposure to high voltage may be harmless, such as the spark produced in a dry climate when touching a doorknob after walking across a carpeted floor.

## Sparks in air

[](http://en.wikipedia.org/wiki/File:Electrostatic-discharge.jpg)

[http://bits.wikimedia.org/skins-1.17/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Electrostatic-discharge.jpg)

Long exposure photograph of a [Tesla coil](http://en.wikipedia.org/wiki/Tesla_coil) showing the repeated [electric discharges](http://en.wikipedia.org/wiki/Electric_discharge)

The [dielectric breakdown](http://en.wikipedia.org/wiki/Dielectric_breakdown) strength of dry air, at [Standard Temperature and Pressure](http://en.wikipedia.org/wiki/Standard_Temperature_and_Pressure) (STP), between spherical electrodes is approximately 33 kV/cm.[[2]](http://en.wikipedia.org/wiki/High_voltage#cite_note-1) This is only as a rough guide, since the actual breakdown voltage is highly dependent upon the electrode shape and size. Strong [electric fields](http://en.wikipedia.org/wiki/Electric_field) (from high voltages applied to small or pointed conductors), often produce violet-colored [corona discharges](http://en.wikipedia.org/wiki/Corona_discharge) in air, as well as visible sparks. Voltages below about 500–700 volts cannot produce easily visible [sparks](http://en.wikipedia.org/wiki/Electric_spark) or glows in air at atmospheric pressure, so by this rule these voltages are "low". However, under conditions of low atmospheric pressure (such as in high-altitude [aircraft](http://en.wikipedia.org/wiki/Aircraft)), or in an environment of [noble gas](http://en.wikipedia.org/wiki/Noble_gas) such as [argon](http://en.wikipedia.org/wiki/Argon), [neon](http://en.wikipedia.org/wiki/Neon), etc., sparks will appear at much lower voltages. Five hundred to 700 volts is not a fixed minimum for producing spark breakdown, but it is a rule-of-thumb. For air at STP, the minimum sparkover voltage is around 327 volts, as noted by [Friedrich Paschen](http://en.wikipedia.org/wiki/Friedrich_Paschen) [[3]](http://en.wikipedia.org/wiki/High_voltage#cite_note-2)

While lower voltages will not, in general, jump a gap that is present before the voltage is applied, interrupting an existing current flow often produces a low-voltage spark or [arc](http://en.wikipedia.org/wiki/Electric_arc). As the contacts are separated, a few small points of contact become the last to separate. The current becomes constricted to these small *hot spots*, causing them to become incandescent, so that they emit electrons (through [thermionic emission](http://en.wikipedia.org/wiki/Thermionic_emission)). Even a small [9 V battery](http://en.wikipedia.org/wiki/9_V_battery) can spark noticeably by this mechanism in a darkened room. The ionized air and metal vapour (from the contacts) form plasma, which temporarily bridges the widening gap. If the power supply and load allow sufficient current to flow, a self-sustaining [arc](http://en.wikipedia.org/wiki/Electric_arc) may form. Once formed, an arc may be extended to a significant length before breaking the circuit. Attempting to open an inductive circuit often forms an arc, since the [inductance](http://en.wikipedia.org/wiki/Inductance) provides a high-voltage pulse whenever the current is interrupted. [AC](http://en.wikipedia.org/wiki/Alternating_Current) systems make sustained arcing somewhat less likely, since the current returns to zero twice per cycle. The arc is extinguished every time the current goes through a [zero crossing](http://en.wikipedia.org/wiki/Zero_crossing), and must reignite during the next half-cycle in order to maintain the arc.

Unlike an ohmic conductor, the voltage at the ends of an arc decreases as the current increases. This makes unintentional arcs in an electrical apparatus dangerous, since, once even a small arc is initiated, if sufficient current is available, the arc will grow. Such arcs can cause great damage to equipment and present a severe fire hazard. Intentionally produced arcs, such as used in lighting or [welding](http://en.wikipedia.org/wiki/Welding), require some element in the circuit to stabilize the arc's current/voltage characteristics.

## Electrostatic devices and phenomena

A high voltage is not necessarily dangerous if it cannot deliver substantial [current](http://en.wikipedia.org/wiki/Electrical_current). The common [static electric sparks](http://en.wikipedia.org/wiki/Electrostatics) seen under low-humidity conditions always involve voltage well above 700 V. For example, sparks to car doors in winter can involve voltages as high as 20,000 V.[[4]](http://en.wikipedia.org/wiki/High_voltage#cite_note-3) Also, physics demonstration devices such as [Van de Graaff generators](http://en.wikipedia.org/wiki/Van_de_Graaff_generator) and [Wimshurst machines](http://en.wikipedia.org/wiki/Wimshurst_machine) can produce voltages approaching one million volts, yet at worst they deliver a brief sting. These devices have a limited amount of stored energy, so the current produced is low and usually for a short time.[[5]](http://en.wikipedia.org/wiki/High_voltage#cite_note-4) During the discharge, these machines apply high voltage to the body for only a millionth of a second or less.

The discharge may involve extremely high power over very short periods, but, in order to produce heart fibrillation, an electric [power supply](http://en.wikipedia.org/wiki/Power_supply) must produce a significant current in the heart muscle continuing for many [milliseconds](http://en.wikipedia.org/wiki/Millisecond), and must deposit a total energy in the range of at least millijoules or higher. In alternative fashion, it must deliver enough energy to damage tissue through heating.

[Tesla coils](http://en.wikipedia.org/wiki/Tesla_coil) are not electrostatic machines and can produce significant currents for a sustained interval.

## Power lines

[](http://en.wikipedia.org/wiki/File:Ligne_haute-tension.jpg)

[http://bits.wikimedia.org/skins-1.17/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Ligne_haute-tension.jpg)

High tension power lines

Electrical transmission and distribution lines for [electric power](http://en.wikipedia.org/wiki/Electric_power) always use voltages significantly higher than 50 volts, so contact with or close approach to the line conductors presents a danger of [electrocution](http://en.wikipedia.org/wiki/Electric_shock). Contact with [overhead wires](http://en.wikipedia.org/wiki/Overhead_wires) is a frequent cause of injury or death. Metal ladders, farm equipment, boat masts, construction machinery, aerial [antennas](http://en.wikipedia.org/wiki/Antennas), and similar objects are frequently involved in fatal contact with overhead wires. Digging into a buried cable can also be dangerous to workers at an excavation site. Digging equipment (either hand tools or machine driven) that contacts a buried cable may energize piping or the ground in the area, resulting in electrocution of nearby workers. A [fault](http://en.wikipedia.org/wiki/Fault_(power_engineering)) in a high-voltage transmission line or substation may result in high currents flowing along the surface of the earth, producing an [earth potential rise](http://en.wikipedia.org/wiki/Earth_potential_rise) that also presents a danger of electric shock.

Unauthorized persons climbing on power pylons or electrical apparatus are also frequently the victims of electrocution.[[6]](http://en.wikipedia.org/wiki/High_voltage#cite_note-NIOSH-5) At very high transmission voltages even a close approach can be hazardous, since the high voltage may spark across a significant air gap.

For high-voltage and extra-high-voltage transmission lines, specially trained personnel use so-called "[live line](http://en.wikipedia.org/wiki/Live-line_working)" techniques to allow hands-on contact with energized equipment. In this case ,the worker is electrically connected to the [high-voltage line](http://en.wikipedia.org/wiki/High-voltage_line) but thoroughly insulated from the earth so that he is at the same electrical potential as the that of the line. Since training for such operations is lengthy, and still presents a danger to personnel, only very important transmission lines are subject to maintenance while live. Outside these properly engineered situations, it should not be assumed that being insulated from earth guarantees that no current will flow to earth as grounding, or arcing to ground, can occur in unexpected ways, and high-frequency currents can cause burns even to an ungrounded person (touching a transmitting [antenna](http://en.wikipedia.org/wiki/Antenna_(radio)) is dangerous for this reason, and a high-frequency [Tesla Coil](http://en.wikipedia.org/wiki/Tesla_Coil) can sustain a spark with only one endpoint).

Protective equipment on high-voltage transmission lines normally prevents formation of an unwanted arc, or ensures that it is quenched within tens of milliseconds. Electrical apparatus that interrupts high-voltage circuits is designed to safely direct the resulting arc so that it dissipates without damage. High voltage [circuit breakers](http://en.wikipedia.org/wiki/Circuit_breakers) often use a blast of high pressure air, a special [dielectric gas](http://en.wikipedia.org/wiki/Dielectric_gas) (such as [SF6](http://en.wikipedia.org/wiki/SF6) under pressure), or immersion in [mineral oil](http://en.wikipedia.org/wiki/Mineral_oil) to quench the arc when the high voltage circuit is broken.

## Arc flash hazard

*Main article:* [*Arc flash*](http://en.wikipedia.org/wiki/Arc_flash)

Depending on the [prospective short circuit current](http://en.wikipedia.org/wiki/Prospective_short_circuit_current) available at a [switchgear](http://en.wikipedia.org/wiki/Switchgear) line-up, a hazard is presented to maintenance and operating personnel due to the possibility of a high-intensity [electric arc](http://en.wikipedia.org/wiki/Electric_arc). Maximum temperature of an arc can exceed 10,000 [kelvin](http://en.wikipedia.org/wiki/Kelvin), and the radiant heat, expanding hot air, and explosive vaporization of metal and insulation material can cause severe injury to unprotected workers. Such switchgear line-ups and high-energy arc sources are commonly present in electric power utility substations and generating stations, industrial plants and large commercial buildings. In the [United States](http://en.wikipedia.org/wiki/United_States), the [National Fire Protection Association](http://en.wikipedia.org/wiki/National_Fire_Protection_Association), has published a guideline standard [NFPA 70E](http://en.wikipedia.org/wiki/NFPA_70E) for evaluating and calculating *arc flash hazard*, and provides standards for the protective clothing required for electrical workers exposed to such hazards in the workplace.

## Explosion hazard

*Main article:* [*Electrical equipment in hazardous areas*](http://en.wikipedia.org/wiki/Electrical_equipment_in_hazardous_areas)

Even voltages insufficient to break down air can be associated with enough energy to ignite atmospheres containing flammable gases or vapours, or suspended dust. For example, [hydrogen](http://en.wikipedia.org/wiki/Hydrogen) gas, [natural gas](http://en.wikipedia.org/wiki/Natural_gas), or [gasoline](http://en.wikipedia.org/wiki/Gasoline) vapor mixed with air can be ignited by sparks produced by electrical apparatus. Examples of industrial facilities with hazardous areas are [petrochemical](http://en.wikipedia.org/wiki/Petrochemical) refineries, [chemical plants](http://en.wikipedia.org/wiki/Chemical_plant), [grain elevators](http://en.wikipedia.org/wiki/Grain_elevator), and [coal mines](http://en.wikipedia.org/wiki/Coal_mine).

Measures taken to prevent such explosions include:

* [Intrinsic safety](http://en.wikipedia.org/wiki/Intrinsic_safety) by the use of apparatus designed not to accumulate enough stored electrical energy to trigger an explosion
* Increased safety, which applies to devices using measures such as oil-filled enclosures to prevent sparks
* Explosion-proof (flame-proof) enclosures, which are designed so that an explosion within the enclosure cannot escape and ignite a surrounding explosive atmosphere (this designation does not imply that the apparatus will survive an internal or external explosion).

In recent years, standards for explosion hazard protection have become more uniform between European and North American practice. The "zone" system of classification is now used in modified form in [U.S.](http://en.wikipedia.org/wiki/United_States) [National Electrical Code](http://en.wikipedia.org/wiki/National_Electrical_Code_(US)) and in the [Canadian Electrical Code](http://en.wikipedia.org/wiki/Canadian_Electrical_Code). Intrinsic safety apparatus is now approved for use in North American applications, though the explosion-proof (flame-proof) enclosures used in North America are still uncommon in Europe.

## Toxic gases

Electrical discharges, including partial discharge and [corona](http://en.wikipedia.org/wiki/Corona_discharge), can produce small quantities of toxic gases, which in a confined space can be a serious health hazard. These gases include [ozone](http://en.wikipedia.org/wiki/Ozone) and various [oxides of nitrogen](http://en.wikipedia.org/wiki/Nitrogen_oxide).

## Lightning

The largest-scale sparks are those produced naturally by [lightning](http://en.wikipedia.org/wiki/Lightning). An average bolt of negative lightning carries a current of 30 to 50 kiloamperes, transfers a charge of 5 [coulombs](http://en.wikipedia.org/wiki/Coulomb), and dissipates 500 [megajoules](http://en.wikipedia.org/wiki/Joule#SI_multiples) of energy (enough to light a 10-watt light bulb for 2 months). However, an average bolt of positive lightning (from the top of a thunderstorm) may carry a current of 300 to 500 kiloamperes, transfer a charge of up to 300 coulombs, have a potential difference up to 1 gigavolt (a billion volts), and may dissipate enough energy to light a 100-watt light bulb for up to 95 years. A negative lightning stroke typically lasts for only tens of microseconds, but multiple strikes are common. A positive lightning stroke is typically a single event. However, the larger peak current may flow for hundreds of milliseconds, making it considerably hotter and more dangerous than negative lightning.

Hazards due to lightning obviously include a direct strike on persons or property. However, lightning can also create dangerous voltage gradients in the earth and can charge extended metal objects such as [telephone](http://en.wikipedia.org/wiki/Telephone) cables, fences, and pipelines to dangerous voltages that can be carried many miles from the site of the strike. Although many of these objects are not normally conductive, very high voltage can cause the [electrical breakdown](http://en.wikipedia.org/wiki/Electrical_breakdown) of such insulators, causing them to act as conductors. These transferred potentials are dangerous to people, livestock, and electronic apparatus. Lightning strikes also start fires and explosions, which result in fatalities, injuries, and property damage. For example, each year in North America, thousands of [forest fires](http://en.wikipedia.org/wiki/Forest_fire) are started by lightning strikes.

Measures to control lightning can mitigate the hazard; these include [lightning rods](http://en.wikipedia.org/wiki/Lightning_rod), shielding wires, and bonding of electrical and structural parts of buildings to form a continuous enclosure.

High-voltage lightning discharges in the atmosphere of [Jupiter](http://en.wikipedia.org/wiki/Jupiter) are thought to be the source of the planet's powerful [radio](http://en.wikipedia.org/wiki/Radio) frequency emissions