Air Blast Circuit Breaker

A circuit breaker using compressed air to force the extinction of the arc through an arc-chute system. An obsolete technology. See also Circuit Breaker.

Air Magnetic Circuit Breaker

A circuit breaker that uses air as its insulating medium, and an arc-chute system for dissipating the arc, a method of generating a magnetic field which forces the arc into the arc chute, and with possible assistance from a air puffer system to blow the arc into the arc chutes. An obsolete technology. See also Circuit Breaker.

ANSI Device Function Numbers

Defined in ANSI standard C37.2, the Device Function Numbers are a world-wide standardized system for describing the function of many protection and control components within switchgear. They are commonly used to describe the type of protection applied to a circuit. For example, the most common form of protection is overcurrent, usually designated as 50/51. This designation actually covers two types of overcurrent protection, 50 which is instantaneous protection, and 51 which is a time overcurrent protection.

Various suffixes can be used, which are sometimes context sensitive. For example, 87 represents differential protection in general, while 87T is specifically transformer differential protection and 87G is specifically generator differential protection. However, 50G refers to instantaneous overcurrent protection on the ground circuit (in this case the G refers to ground, not generator). Refer to the ANSI standard for a full explanation.

ANSI Standards

The American National Standards Institute control the National Standards of the United States. These standards are of course used in the US and some are used by certain other countries as well, including Canada. The electrical engineering standards of ANSI are often written for them by IEEE, the Institute of Electrical and Electronics Engineers.

ANSI Switchgear

Not a definitive term, but used to generally describe switchgear built in accordance with ANSI standards, as opposed to IEC standards (IEC Switchgear).

Anti-single Phase Tripping Device

A device that operates to open all phases of a circuit by means of a polyphase switching device, in response to the interruption of the current in one phase. For example, the striker pin of an expulsion fuse can be used to actuate a common tripping bar which causes a three phase load break switch to open.

Anti-pumping Relay

Anti pumping relay is device used in association with a circuit breaker to prevent the circuit breaker from reclosing after an opening operation, as long as the device initiating the reclosing is maintained in the position for closing. For example, as long as the opening coil is energized, then any attempt to close the circuit breaker will not work.

Arc-chute

A structure used as part of a current interrupting device, affording a confined space or passage, lined with arc-resisting material, through which an arc is directed in order to cause it to extinguish.

In medium voltage switchgear, this was the main current interrupting means in the air-magnetic type of circuit breakers, but the same concept does not exist in vacuum or SF6 designs. Arc-chutes are common in low voltage circuit breakers.

Arc-resistant Switchgear
A type of switchgear design which is designed to withstand the effects of an internal arcing fault, without causing harm to personnel who are located in defined areas. It is not intended to withstand these internal arcing fault without possibly causing physical damage to the structure and/or components, but often the physical damage is less with an arc-resistant design.

**There are three classes of protection:**
- **Type A** eliminates the emission of gases and particles from the front of the switchgear during an internal arcing fault,
- **Type B** eliminates the emission of gases and particles from the front and sides of the switchgear during an internal arcing fault,
- **Type C** eliminates the emission of gases and particles from the front and sides of the switchgear, from between compartments within the same cell, and between adjacent cells during an internal arcing fault.

Arc-resistant switchgear has traditionally been metal-clad, but the basic concept could also be applied to other types of switchgear as well. See also Proof, Resistant.

**Arc-proof Switchgear**

An incorrect term. Please refer to Arc-resistant Switchgear, Proof, Resistant.

**Arcing Contacts**

The contacts of a switching device upon which the arc is deliberately drawn after the main contacts have parted. See also Main Contacts.

**Arcing Time**

The amount of time between the first initiation of the arc and the instant of final arc extinction in all phases. See also Opening Time, Closing Time.

**Asymmetrical Current**

The current which appears in a circuit during fault conditions, composed of the total of the AC component of the fault current and the DC offset component.

**Auxiliary Circuits**

All the control, indicating and measuring circuits in the switchgear. When speaking of the circuit breaker, these are often called the secondary circuits (with the main current path called the primary circuit).

**Auxiliary Relay**

A relay whose function is to assist another relay or control device in performing a general function by supplying supplementary actions. Some examples are a relay used to provide seal-in functions, to increase the number of available contacts, to provide circuit opening instead of circuit closing contacts or vice-versa etc.

**Backfeed**

To energize a section of a power network, supplied from a source other than its normal source. This may be a desired state, or may be non-desired if the circuit is thought to be deenergized with the main incoming device turned off, but is actually being backfed, for example, through the secondary of a transformer.
It is known that workers are sometimes injured when they try to work on a system they think is deenergized but is actually backfed from a source they did not know about.

**BIL (Basic Impulse Insulation Level)**

A reference impulse insulation strength expressed in terms of the crest value of the withstand voltage of a standard full impulse voltage wave. It is commonly used to define the overall insulation strength of the design, with other test levels (e.g. applied tests) related in a standard method to the BIL.

Typically 5 kV class switchgear is 60 kV BIL, 15 kV class switchgear is 95 kV BIL, 25 kV class switchgear is 125 kV BIL (although 150 kV BIL is not uncommon at 27.6 kV), and 38 kV class switchgear is 150 kV BIL (with some requests for 170 or 200 kV BIL at times).

**Bifurcated Feeder**

A feeder connection where two loads are connected to one power source. Higher number of connections are also possible, such as trifurcated feeders for three loads etc.

**Bolted Fault**

A short circuit condition that assumes zero impedance exists at the point of the fault, as if a heavy bus bar was solidly bolted across the point of the fault. This assumption is typically used to calculate the worst-case fault current levels.

This term can also imply a fault that does not burn away in any reasonable time, but must be actually removed or repaired.

**Burden (of a Relay)**

The load impedance imposed by a relay on its source, expressed in ohms and phase angle at specified conditions.

Modern solid state protective relays have very small burdens, while some older electromechanical relays had significant burdens, requiring the use of high output instrument transformers to drive them.

**Bus**

A conductor, or group of conductors, which serve as a common connection for two or more circuits. In practice, “bus” generally refers to the main power bus in the switchgear, but it could also refer to a data bus, or ground bus etc.

**Bus Duct**

See Metal-enclosed Bus, Isolated Phase Bus Duct.

**Bushing**

An insulating structure including a through conductor, or a passageway for such a conductor, with provision for mounting on a barrier (conducting or insulating), used for the purpose of insulating the conductor from the barrier and conducting current from one side of the barrier to the other.

Bushings may use porcelain, epoxy or other type of insulating material in the structure, be smooth surfaced or with sheds to increase the creepage distance. In metal-clad switchgear, bushing is sometimes the term used to describe the assembly of the primary disconnect system (the term “spouts” is also used).
**Cartridge Fuse**

A low voltage fuse consisting of a current-responsive element inside of a fuse tube with connection terminals on both ends. Commonly used to protect control circuits in the switchgear LV control cabinet.

**Cassette**

An assembly which provides all the necessary mechanical and electrical interlocks, circuit breaker supports, shutter mechanism, racking mechanism etc. for a withdrawable circuit breaker, and which comprises nearly the entire circuit breaker compartment. It still requires the front door to be added, and the other switchgear compartments as well (low voltage, main bus, cable etc.). Typically supplied to OEM switchgear manufacturers when they purchase a circuit breaker from a primary manufacturer so that they do not have to design all of these components themselves. See also Cradle.

**Closing Time**

The amount of time from the initiation of the closing operation and the instant when metallic continuity is established in all phases. See also Opening Time, Arcing Time.

**Circuit Breaker**

A mechanical switching device, capable of making, carrying and interrupting currents under normal circuit conditions, and also making and carrying for specified time and interrupting current under abnormal circuit conditions such as those occurring during short circuits.

Many different methods of achieving this functionality have been developed over the years, such as Air-blast, Air-magnetic, Minimum Oil, Bulk Oil, etc., but most modern medium voltage applications today use either SF6 or Vacuum methods. Circuit breakers are usually intended to operate infrequently, although some types are made to operate frequently.

**Circuit Switcher**

A mechanical switching device with an integral interrupter, suitable for making, carrying and interrupting currents under normal circuit conditions. It can also interrupt specified short circuit currents which may be less than its close and latch, momentary and short time current ratings. It is usually less expensive than a circuit breaker, but does not achieve the same performance level.

**Clearing Time**

For a circuit breaker, it is the interval between the time the actuating quantity in the main circuit reaches the value causing actuation of the release and the instant of final arc extinction on all poles of the primary arcing contacts. It is numerically equal to the sum of the contact parting time plus the arcing time.

For a fuse, it is the interval between a specified overcurrent to the final circuit interruption at rated maximum voltage. It is equal to the sum of the melting time plus the arcing time.

**Close And Latch**

The rating of the ability of a circuit breaker or other switching device to close against the electromagnetic forces (which are trying to force the contacts open), to latch into the closed position, and to carry a specified current through the device under specified conditions. This is mostly related to ensuring the operating mechanism has sufficient mechanical energy to overcome the electromagnetic forces.

**Close-Open Operation**

A close operation of the switching device, followed immediately by an opening operation, without introducing any deliberate time delay. It is commonly shown as CO.
**Closing Coil**

A coil in the electromagnet that supplies power for closing the device, such as the circuit breaker. It must be specified to have the correct control voltage rating for the installation.

**Compartment**

Inside of a cell of metal-clad switchgear, there are different and separate compartments used to segregate different components and functions from one another, to improve reliability and improve safety. Each compartment is separated by a grounded metal barrier. Standard compartments are low voltage, circuit breaker, main bus and cable, with other compartments possible as the design demands.

**Conformance Tests**

Those tests made to demonstrate compliance with the applicable standards, such as CSA, ANSI or IEC. These tests are generally performed after the test item has been subjected to all of the required production tests. Demonstration of margin (capability) beyond the requirements of the standards is not required. See also Design Tests, Production Tests.

**Connected Position (of a Circuit Breaker)**

That position of the removable element in which both the primary and secondary disconnecting devices are in full contact. See also Disconnected Position, Test Position.

**Contactor**

A contactor is (usually) a magnetically operated switch for repeatedly establishing and interrupting an electric power circuit. It may also include a mechanical latching system to hold the contactor closed without requiring a continuous power supply.

A typical application is motor starting. It differs from a circuit breaker in that it will withstand a very high number of operations (300,000 or more compared to 10,000 for a circuit breaker), has generally lower continuous current ratings than ANSI circuit breakers and has lower interrupting and making capacities. It is not intended to interrupt fault current on its own and is therefore often used in association with fuses or a circuit breaker. See also Circuit Breaker.

**Control Power Transformer (CPT)**

A transformer used to supply control power to switchgear. It is connected to the main switchgear bus as its power source, is usually single phase only, and is usually 120 volts output (other voltages are possible). It is often a VT located in a standard VT drawer, but may be a small power transformer if a sufficiently high power output is required.

**Control Relay**

An auxiliary relay whose function is to initiate or permit the next desired operation in a control sequence.

**Control Voltage**

The voltage of the power supply used to energize a device in the switchgear. Typical voltages are 24, 48, 60, 110, 125, 220 or 250 volts DC, and 120, 127, 220 or 250 volts AC.

**Control Wiring**

See Secondary and Control Wiring.

**Conversion (of Switchgear)**

A general term pertaining to the process of altering existing power switchgear equipment. Conversion can involve as little as replacing the main or arcing contact tips with other than the original design material, to replacing the entire arc-interrupting structure.
Changeover of an existing air-magnetic circuit breaker to an SF6 or vacuum design is properly called a conversion (not retrofit as is commonly used). See also Reconditioning.

Corona

An electrical discharge in air that only partially bridges the gap between two or more electrodes. Corona leads to power loss (although this is fairly minor at medium voltage) and causes radio interference, as well as leading to physical damage of the insulation over time if it is severe enough.

Corona can be tested by measuring the discharge magnitude using a radio receiver, and this is then referred to as a Radio Influence Voltage (RIV) Test. See also Partial Discharge.

CPT

See Control Power Transformer.

Cradle

An assembly which provides all the necessary mechanical and electrical interlocks, circuit breaker supports, shutter mechanism, racking mechanism etc. for a withdrawable circuit breaker, which is intended in turn to be installed inside of a switchgear cell manufactured by others.

Typically supplied to OEM switchgear manufacturers when they purchase a circuit breaker from a primary manufacturer so that they do not have to design all of these components themselves. See also Cassette.

Creepage Distance

The shortest distance along the surface of an insulator from one conducting part to another, which may be energized or at ground potential. When designing the device, the Creepage Distance must be long enough that it will withstand the highest voltage foreseen for the installation within the specified conditions (such as pollution or moisture). See also Strike Distance.

CSA Standards

CSA is the acronym for the Canadian Standards Association. The National Standards of Canada are published and controlled by the Canadian Standards Association. CSA has both mandatory standards and performance standards.

There are mandatory standards published relating to switchgear, which are safety related.

Current Injection

A synthetic test method where current is injected into a circuit in order to determine the operating characteristics of other components connected to it. For example, it can be used to inject primary current into a current transformer, to monitor what happens to secondary devices attached to the current transformer secondary.

Current Limiting Fuse (CLF)

A fuse unit that when it is melted by a current within its specified current limiting range, abruptly introduces a high resistance to reduce the current magnitude and duration. CLF’s are used to limit damage to equipment by dramatically reducing the energy let-through of the fuse.

Current Transformer

A transformer specially designed to accurately represent the primary current in a secondary circuit. Typically in North America, current transformers are standardized to be 5 amperes when rated current is passed through the primary circuit, although other values are possible.

Current transformers can be used to power or provide information to such equipment as metering devices, or protective relays.
Dead-tank

A switching device in which a vessel at ground potential surrounds and contains the interrupter and insulating medium. Metal-enclosed and metal-clad switchgear are obviously of dead front design, as are station breakers.

Dead Time

Usually referencing a circuit breaker on a reclosing operation, Dead Time refers to the interval between interruption on all poles on the opening stroke, and the re-establishment of the circuit on the reclosing stroke.

Definite Time Relay

A relay in which the operating is substantially constant regardless of the input quantity. See Inverse Time.

Derating Factors

There are a number of derating factors possible for switchgear. The two most common are related to altitude above sea level. At high elevations, the breakdown strength of air decreases, and its ability to remove heat also decreases.

Other derating factors may involve high ambient temperatures, high harmonics in the power system etc.:

- **Voltage:** At and below 1000 meters, the normal rating applies. At 1500 meters elevation, the voltage must be reduced to 95% or clearances increased accordingly. At 3000 meters, the voltage must be reduced to 80% or clearances increased accordingly. Intermediate values may be obtained by interpolation. Surge arresters are strongly recommended at any elevation above 1000 meters.
- **Current:** At and below 1000 meters, the normal rating applies. At 1500 meters elevation, the current must be reduced to 99% or conductor cross sections increased accordingly. At 3000 meters, the current must be reduced to 96% or conductor cross sections increased accordingly. Intermediate values may be obtained by interpolation.

Design Tests

Those tests made to determine the adequacy of a particular type, style or model of equipment, with all of its component parts, to meet its assigned ratings and to operate satisfactorily under its normal service conditions, or under special service conditions if specified.

These tests are usually performed on representative apparatus, and are not intended to be performed on a regular production basis. These tests are sometimes called Type Tests. See also Conformance Tests, Production Tests.

Differential Protection

A method of protecting apparatus in which an internal fault is identified by comparing the electrical conditions on the terminals of the apparatus. In the case of busbar differential protection, it is very straightforward (the current that goes in must exactly equal the current that goes out).

In the case of motors or transformers, then special consideration must be given to inrush currents, and in the case of transformers, to the turns ratio and winding connections as well.

Direct Acting Overcurrent Trip Device

A release or tripping system that is completely self contained on a circuit breaker and requires no external power or control circuits to cause it to function.
Disconnected Position (of a Circuit Breaker)

That position in which the primary and secondary disconnecting devices of the removable element are separated by a safe distance from the stationary element contacts. See Connected Position, Test Position.

Disconnecting Switch

Same as Isolating Switch. A mechanical switching device used for changing the connections in a circuit, or for isolating a circuit or equipment from the source of power.

It is required to carry normal load current continuously, as well as abnormal or short circuit currents for short times as specified. It is required to open or close circuits when negligible current is interrupted or made.

Dual Element Fuse

A fuse having responsive elements of two different fusing characteristics in a single series of fuse. See also Single Element Fuse.

Duty Cycle

A prescribed sequence of operations for a specific time, with specific time intervals between sequences. For example, a motor may only be allowed to have a certain number of starts per hour, due to the overheating effect of the high starting current.

The motor must be given time to cool off between starts in order to maintain the normal life expectancy.

Earth Fault Protection

Same as Ground Fault Protection. “Earth” is typically the terminology used in Europe, “Ground” being used in North America.

Electrically Trip Free

A term applied to electrically operated switching devices such as circuit breakers, indicating that the opening release can open the device even though the closing release circuit is energized.

Electrically trip free devices are also usually designed with an anti-pumping relay, so that the closing mechanism will not reclose the switching device after opening until the closing control circuit is opened and again closed.

Electromagnetic Compatibility (EMC)

A measure of the tolerance of equipment to external electromagnetic fields. It is very important for electronic devices (for example) that are used in power equipment to have a high tolerance to electromagnetic fields.

Expulsion Fuse

A vented fuse or fuse unit in which the expulsion effect of gases produced by the arc and the lining of the fuse holder, either alone or aided by a spring, extinguishes the arc.
Feeder

A section of a switchgear assembly which supplies a load. A simple switchgear assembly typically consists of an incomer (supplying power to the switchgear), a number of feeders (supplying power to various loads so that they can be individually switched and/or protected), and perhaps a tie (to connect to another switchgear assembly).

Ferroresonance

An electrical resonant condition associated with the saturation of a ferromagnetic device, such as a transformer, through capacitance.

Ferroresonance can arise, for example, when a weak source is isolated with a lightly loaded feeder containing power cables or power factor correction capacitors. Ferroresonance can produce dangerously high voltages which can cause equipment damage or failure.

Fuse

An overcurrent protective device with a circuit opening fusible part that is heated and severed by the passage of current through it.

The term fuse comprises all the parts that form a unit capable of performing the prescribed function, but it may or may not be the complete device necessary to connect it into an electric circuit. See Cartridge Fuse, Current Limiting Fuse, Fuse Link, Expulsion Fuse.

Fuse Link

A replaceable part or assembly, comprised entirely or principally of the conducting element, required to be replaced after each circuit interruption to restore the fuse to operating conditions.

GIS Gas Insulated Substation

GIS equipment is a type of metal-clad switchgear construction, where all the switchgear power components are located inside of a sealed metal envelope filled with (usually) SF6 gas.

GIS equipment is often supplied into high voltage applications, but there are now offerings at medium voltage. GIS has small space requirements, is impervious to atmospheric contaminants and no derating is required for high elevations.

Ground and Test Device (GATD)

A term applied to a switchgear accessory device that can be inserted in place of the drawout circuit breaker for the purpose of either grounding the main bus and/or the external circuits connected to the switchgear assembly, and/or primary circuit testing.

A normal GATD can carry the same full fault current of the switchgear assembly for a specified time. Optionally, a modified circuit breaker can be used to provide the GATD functions and in addition allow full fault switching capability.

Ground Bus
A bus to which the grounds from individual pieces of equipment are connected, and that in turn is connected to ground at one or more points. Typically in metal-enclosed switchgear, the ground bus is not insulated, and is extended into every cell and every compartment in each cell (except the main bus compartment).

Ground Fault Protection

A method of protection in which faults to ground within the protected equipment are detected and action taken (alarm, trip etc.). Ground faults are usually detected using zero-sequence current transformers as the sensors.

Grounding Switch

A mechanical switching device by means of which a circuit or piece of apparatus may be electrically connected to ground.

The switch may or may not have fault making capabilities. Integrated grounding switches are common in European switchgear designs, but are rare in North American designs, although their popularity is slowly growing.

Handling Device

That accessory used with metal-clad switchgear, used for the removal, replacement or transportation of the removable element (e.g. circuit breaker). Not all metal-clad designs require the use of a Handling Device to move the circuit breakers, but many do.

High Speed Relay

In current practice, a relay that operates in less than 50 ms (milliseconds), which is less than three cycles on a 60 Hz system.

IEC Standards

The acronym for the International Electrotechnical Commission.

This series of standards is produced by the IEC, and are typically used in most countries of the world, but not widely in North America. Each country may adapt IEC standards to their own needs, especially in the past, but it is now preferred that the basic standard be applied as is, where possible. When it comes to switchgear and circuit breaker design and ratings, the two main global standards are IEC and ANSI.

The world is very slowly moving towards adopting IEC standards, but ANSI and IEC are different enough that this is not easy to do.

Interlock
A device actuated by the operation of some other device with which it is directly associated, to govern succeeding operations of the same or allied devices. Interlock systems are a series of interlocks applied to associated equipment in such a manner as to prevent or allow operation of the equipment only in a prearranged sequence.

There are three main types of interlocks, namely mechanical, electrical and key. Mechanical and electrical interlocks are always present in some way in switchgear to provide for safe operation of the basic equipment. Key interlocks are typically more of an optional accessory used to provide customer prescribed operation sequences.

Interrupter Switch

An air insulated switch, equipped with an interrupter, for making or interrupting specified currents, or both. The nature of the current being made or interrupted is indicated by a suitable prefix, such as “load interrupter switch”, “fault interrupter switch”, “capacitor current interrupter switch”, etc.

Inverse-time Relay

A relay in which the input quantity and operating time are inversely related throughout at least a substantial portion of the performance range. Various adjectives are commonly used to illustrate the level of inverseness of the operating characteristics, such as “standard”, “very”, “extremely”, “ultra” etc. See also Definite Time Relay.

Isolated Phase Bus

A bus in which each phase conductor is enclosed by an individual metal housing separated from adjacent conductor housings by an air space. The bus may be self cooled or may be forced cooled, using gas or liquid. Isolated phase bus is commonly used at very high current ratings, such as the output of large generators.

Isolating Switch

Same as Disconnecting Switch. A mechanical switching device used for changing the connections in a circuit, or for isolating a circuit or equipment from the source of power. It is required to carry normal load current continuously, as well as abnormal or short circuit currents for short times as specified. It is required to open or close circuits when negligible current is interrupted or made.

Key Interlock

See Interlock.

Load Break Switch

See Load Interrupter Switch.

Load Interrupter Switch
An interrupter switch designed to interrupt currents which are not in excess of the continuous current rating of the switch. It may be designed to close and carry abnormal or short circuit currents as specified. Also colloquially referred to as a Load Break Switch.

Load Shedding

The process of deliberately removing preselected loads from a power system in response to abnormal conditions, in order to maintain the integrity of the power system.

Load shedding can also be used to reduce demand in a specified part of a power distribution system for economic reasons e.g. an industrial customer may shed specific loads to keep their kilowatt demand below a price increase threshold (kW demand is often priced based on the peak usage in a calendar year, so keeping the demand below a certain level can affect a whole year’s electrical billing).

Main Contacts

The main continuous current carrying contacts in a current interruption device. Typically, the interruption device is designed so that the main contacts never see arcing themselves, that function being provided by arcing contacts specifically designed to do so. Main contacts are sometimes referred to as the Primary Contacts. See also Arcing Contacts.

Main Connections

Those that electrically connect together devices in the main circuit, or connect them to the bus, or both. Also referred to as the Primary Connections.

Maintenance Interval

The period, which can be defined in terms of real time, operating time, number of operating cycles or a combination of these, during which satisfactory performance is expected without maintenance or adjustment.

Margin

The difference between the demonstrated capability of the equipment and that required in-service for specific conditions.

Medium Voltage

The term medium voltage refers to voltages above 1,000 volts and below 69,000 volts. The highest voltage metal enclosed switchgear in general use in North America is generally 38 kV class, although there is a small amount of 44 kV. Usually at 44 kV and above, switching is achieved by the use of air-insulated substations with discreet components.

Metal-clad Switchgear

Metal-clad switchgear is a specific type of metal-enclosed switchgear. While all metal-clad switchgear is metal-enclosed, not all metal-enclosed switchgear can be classified as metal-clad.

Metal-clad is characterized by always having the following features:
• The main switching and interrupting device is removable (drawout), with a mechanism to move it between connected and disconnected positions, and equipped with self-aligning and self-coupling primary disconnecting devices and disconnectable control wiring connections.
• Major parts of the primary circuit are completely enclosed by grounded metal barriers that have no intentional openings between compartments. A metal barrier shall be included in front of or part of the circuit interrupting device to ensure that when in the connected position, no primary circuit components are exposed by the opening of a door.
• All live parts are enclosed within grounded metal compartments.
• Automatic shutters that cover primary circuit elements when the removable element is in the disconnected, test or connected positions.
• Primary bus conductors and connections are covered with insulating material throughout.
• Mechanical interlocks are provided for proper operating sequence under normal operating conditions.
• Instruments, meters, relays etc. and their wiring are isolated by grounded metal barriers from all primary circuit elements (short lengths of wire such as CT secondary leads are excepted).
• The door through which the removable element is inserted may serve as an instrument or relay panel, and may also provide access to the control compartment within the housing.
• Note the proper spelling of metal-clad, with a dash and a lower case “c”.

Metal-enclosed Switchgear

Switchgear which is surrounded by a metal case or housing, usually grounded. Note the proper spelling of metal-enclosed, with a dash and a lower case “e”.

Metal-enclosed Bus

An assembly of conductors with their associated connections, joints and insulating supports within a grounded metal enclosure.

The conductors may be rigid or flexible (if the flexible conductors are individual cables, then it may be called “cable bus”). There are three types of metal-enclosed bus:

• Nonsegregated-phase bus, in which all phase conductors are in a common metal enclosure without barriers between phases. If associated with metal-clad switchgear, then the primary bus and connections shall be covered with insulating material equivalent to the switchgear insulation system.
• Segregated-phase bus, in which all phase conductors are in a common metal enclosure but are segregated by metal barriers between phases.
• Isolated-phase bus, in which each phase conductor is enclosed by an individual metal housing separated from adjacent conductor housings by an air space. The bus may be self cooled or may be forced cooled, using gas or liquid.

Minimum Oil Circuit Breaker

A circuit breaker using a relatively small quantity of mineral oil for its arc-interruption method. A low cost but now obsolete technology. See also Circuit Breaker.

MOC

Mechanism Operated Contacts. A set of auxiliary switches generally containing both NO and NC contacts, operated by the operating mechanism of a circuit breaker. They are used to signal the current state and the change of state of the circuit breaker operating mechanism.

MTB

Mean Time Between Failures. The time interval, usually expressed in hours, that may be expected between failures of a piece of operating equipment.
Mean Time To Repair. The time interval, usually expressed in hours, that may be expected to return failed equipment to proper operation.

Mimic Bus

A single line diagram of the main connections of a system, constructed on the face of a switchgear or control panel or assembly.

Momentary Current

The current flowing in a device, an assembly or a bus at the major peak of the maximum cycle as determined by the envelope of the current wave.

Multi-pole Operation

A descriptive term indicating that all poles of the device are mechanically or electrically linked such that they change state (open or close) substantially simultaneously.

Natural Frequency

A mechanical term, used to describe the frequency at which a body vibrates due to its own physical characteristics (mass, shape) and electric restoring forces brought into play when the body is distorted in a specific direction and then released while restrained or supported at specific points.

In general switchgear usage, generally important only for seismic analysis.

Nominal System Voltage

A nominal value assigned to designate a system of a given voltage class. For example, in the 15 kV voltage class, a Nominal System Voltage may be 13.8 kV, or 12.47 kV, or other.

Octave

The interval between two frequencies that have a frequency ratio of two. For example, 1 to 2 Hz, 4 to 8 Hz, 64 to 128 Hz.

May be used in discussion of harmonics, or sound level spectrum analysis.

Opening Time

The amount of time between the moment the actuating quantity of the release circuit reaches its operating value, and the instant the primary contacts have parted. Typically, any intentional time delays which may be a part of normal operation are reduced to zero for the purposes of determining opening time.

Operating Mechanism

As part of a switching device, the part of the mechanism that actuates all the main circuit contacts of the switching device either directly or by the use of a pole-unit mechanism.
Partial Discharge

A localized electric discharge resulting from ionization in an insulation system when the voltage stress exceeds the critical value. This discharge partially bridges the insulation between electrodes.

It is commonly used as a test to monitor the quality of manufacture of moulded or cast components (such as current or voltage transformers, or stand-off insulators). If the discharge occurs in air, then it may also be referred to as corona discharge.

Pickup (of a relay)

The action of a relay as it makes designated response to progressive increase of input. As a qualifying term, it is the state of a relay when all response to progressive increases of input has been completed.

Pickup is also used to identify the minimum value of an input quantity reached by progressive increases that will cause the relay to reach the pickup state from reset. Pickup is also used to denote contact operation on relays having multiple inputs, but in this case the pickup value of any input in meaningful only when related to all other inputs.

Pilot Protection

A form of line protection that uses some sort of a communications channel as a means to compare electrical conditions at the terminals of a line. The communications channel may be metallic conductor, fiber optic cable, microwaves etc.

Pilot Wire Protection

Pilot protection in which a metallic circuit is used for the communicating means between relays at the circuit terminals.

Plating (of Joints)

Copper (or aluminium) forms an oxide layer which will commonly cause a joint to have increased resistance and a higher temperature rise. To obtain satisfactory lifetime performance, the high power joints in the main bus system are plated with another metal, usually silver. Silver is the most conductive of all metals, and provides good service with only a very thin plating thickness required (“flash” plating).

For very polluted environments, especially those containing high levels of sulphur, tin plating is used, as the silver will rapidly tarnish. While tin is very stable in most atmospheres, it naturally provides a higher resistance joint than silver, and therefore it is only used where its non-corroding properties are really required.

Pole

That portion of the device associated with one electrically separated conducting path of the main circuit of the device. The poles may be separate for each phase, or may be combined into a unified enclosure.

Potential Transformer

An obsolete name for Voltage Transformer. See also Voltage Transformer.
Prestrike

The initiation of current between the contacts during a closing operation before the contacts have mechanically touched. See also Restrike.

Primary

Used as an adjective, primary can mean:

- the first to operate e.g. primary arcing contacts
- the first in preference e.g. primary protection
- the main circuit as opposed to auxiliary or control circuits e.g. primary disconnecting device
- the energy input side of a transformer (not necessarily the high voltage side)

Production Tests

Those tests made to check the quality and uniformity of the workmanship and materials used in the manufacture of switchgear or its components. Performed on each switchgear that has been manufactured. See also Conformance tests, Design Tests.

Proof

So constructed, protected or treated so that successful operation is not interfered with when the device is subjected to the specified material or condition.

For example, a sprinkler-proof switchgear can continue to operate if the fire protection sprinklers are operating. As another example, the reason that the term arc-proof switchgear is not acceptable as a term, is that in the case of an internal arcing fault, the switchgear cannot usually continue to be used until clean-up and repairs are completed. See also Resistant.

Protection Relay

A relay whose function is to detect defective lines or apparatus, other power system conditions of an abnormal or dangerous nature and to initiate appropriate control circuit action.

A protective relay may be described according to its input quantities (e.g. negative phase sequence relay), operating principles (e.g. differential protection) or performance characteristics.

Quick-break

A term used to describe a device that has a high contact opening speed which is independent of the operator.

Quick-make

A term used to describe a device that has a high contact closing speed which is independent of the operator.
Racking (a Circuit Breaker)

The process of moving a circuit breaker or other removable element from the disconnected position to the test position (if the test position is a different physical position) and into the connected position, or vice-versa. Racking may be performed manually with the door open (rare in a modern switchgear design), manually with the door closed (referred to as through-the-door racking) or electrically with the door closed.

For safety reasons, through-the-door racking systems are preferred, and are essentially required for arc-resistant designs.

Rated Operation Sequence

A standard operating sequence that a circuit breaker has been tested in accordance with. Under ANSI testing rules, the Rated Operation Sequence is a close-open operation, followed by a 15 second delay to allow the operating mechanism to recharge, and then a second close open operation. This is represented by CO – 15s -CO. Note that a fully tested ANSI circuit breaker has been tested for many other operation sequences as well.

Under IEC testing rules, there are three common Rated Operation Sequences. The first is an open operation, followed by three minutes for cooling of the contacts, followed by a CO operation, then 3 minutes, then a final CO (O – 3 min – CO – 3 min – CO). The second is a O – 0.3s -CO – 15 s – CO. The third is O – 0.3 s -CO – 3 min – CO.

Reconditioning (of switchgear)

A general term covering the process of maintaining existing switchgear equipment in operating condition as recommended by the manufacturer’s instructions, using only the original manufacturers recommended replacement parts, without altering the original design. See also Conversion (of Switchgear).

Recovery Voltage

The voltage that appears across the terminals of a pole of a circuit interrupting device upon interruption of the current. See also RRRV.

Refurbishment (of Switchgear)

See Reconditioning (of Switchgear).

Removable Element (of a Switchgear Assembly)

The portion that normally carries the circuit switching and circuit interrupting devices and the removable part of the primary and secondary disconnecting devices. In metal-clad switchgear, generally the circuit breaker is the removable element.

Renewal Parts

Those parts that must be replaced during maintenance as a result of wear.

Resistant (used as suffix)

So constructed, protected or treated that damage will not occur readily when the device is subjected to the specified material or condition. See Arc-resistant Switchgear, Proof.

Restricted Ground Fault

Also called Restricted Earth Fault in Europe. Restricted refers to the “zone” that is being protected, just as differential protection operates over a defined protection zone. It is often used to protect a specific machine such as a motor. See also Zone of Protection.
**Restrike**

A resumption of current between the contacts of a switching device during an opening operation after an interval of zero current of 1/4 cycle at normal frequency or longer. It is preferable that restrikes do not occur as they can stress the attached equipment by causing high recovery voltages. See also Prestrike.

**RIV**

Radio Influence Voltage. Please refer to Corona, Partial Discharge.

**Rowgowski Coil**

Essentially an air cored current transformer which, because it does not have a magnetic core, has a linear response from zero current to very high values (well beyond what can be seen in any short circuit fault current in a power system) and will not saturate.

Rowgowski coils provide a voltage output directly related to the current passing through the primary (e.g. 1 mV/A). Rowgowski coils measure only the AC component of the current, not the DC component. The manufacture of a good Rowgowski coil requires very precise winding of the coil. If the coil is wound properly, then the output does not depend on the position of the central conductor in the coil window.

Generally, the output of a Rowgowski coil is connected to an integrator circuit which provides an output waveform.

**Routine Tests**

See Production Tests.

**RRRV**

Rate of Rise of Recovery Voltage. When current is interrupted quickly, a recovery voltage is generated, and the faster the rate of change of current, the higher the recovery voltage becomes. It is important for a switching device to reform the dielectric breakdown strength of its interrupting medium quickly following the breaking of the current, in order to be able to withstand the recovery voltage generated.

A switching device that can withstand a high recovery voltage will be less likely to restrike. See also Recovery Voltage, Restrike.

**Seal-in Relay**

An auxiliary relay that remains picked up through one of its own contacts, which bypasses the initiating circuit until deenergized by some other device.

For example, if a pressure switch is temporarily closed due to a momentary pressure surge, a seal-in relay can be used to show it had tripped though an annunciator panel, until the operator manually resets it.

**SCADA**

An acronym for Supervisory Control And Data Acquisition. A system operating with coded signals over communication channels so as to provide control of remote equipment, typically using one communications channel per remote station.
The supervisory system may be combined with a data acquisition system by adding the use of coded signals over communication channels to acquire information about the status of the remote equipment for display or recording functions.

Typical supervisory control functions are:

- Alarm functions
- Analogue functions
- Control functions
- Indication or status functions
- Sequence of events function

Secondary

Used as an adjective, secondary can mean:

- operates after the primary device e.g. secondary arcing contacts
- second in preference
- referring to auxiliary or control circuits as contrasted with the main circuit e.g. secondary disconnecting devices, secondary and control wiring
- referring to the energy output side of transformers (which does not have to be the low voltage side)

Secondary and Control Wiring

Wire used with switchgear assemblies for control circuits and for connections between instrument transformer secondaries, instruments, meters, relays, or other equipment.

Secondary Disconnecting Device

Self-coupling separable contacts provided to connect and disconnect the auxiliary and control circuits between the removable element and the housing.

Sequence Currents

The set of currents that when combined, accurately and fully represent the total current in a polyphase system. Consists of positive sequence, negative sequence and zero sequence currents.

SF6

Sulphur Hexafluoride, a gaseous dielectric for high and medium voltage power application, used as an insulator and/or interrupting medium. The highly stable SF6 molecule consists of one central atom of sulphur (S) surrounded by 6 atoms of Flourine (F).

Short Circuit

An abnormal connection, including an arc, of relatively low impedance, whether made accidentally or deliberately, between two or more points of different potential.

Short Line Fault

A fault which occurs close to the terminals of the circuit switching device may cause a different recovery voltage waveform to be generated, essentially adding a high frequency sawtooth waveform to the voltage waveform. As the distance to the fault increases, the amplitude of the sawtooth component increases, but the rate of rise decreases, and the fault current decreases.

The increased amplitude of the voltage negatively affects the interrupting capability of the circuit switching device while the decrease in rate of rise and the decrease in current makes interruption easier. Since the effects are not proportional, a distance is reached
where the affect on interruption is most severe, even though the current is less than for a terminal fault. The critical distance depends on the type of interrupting medium used (air, oil, SF6 or vacuum) and with the particular design of device.

At higher voltages, the critical distance may be on the order of 1.5 km, while at medium voltages the distance is less. See also Terminal Fault.

Shunt Release

A release, typically used to trip a circuit breaker or switch, which is energized by a source of voltage, which may be derived from either the main circuit or from an independent source. The voltage is applied only when tripping is desired. See also Undervoltage Release.

Shutter

A device that is automatically operated to completely cover the stationary portion of the primary disconnecting devices when the removable element is either in the disconnected position, the test position, or has been completely removed. Grounded metal shutters are usually preferred for safety reasons, but insulating materials may also be used in some applications.

Single Element Fuse

A fuse having a current responsive element comprising one or more parts with a single fusing characteristic. See also Dual Element Fuse.

Sound Level

A weighted Sound Pressure Level obtained through the use of a metering characteristic and a weighting algorithm.

Typically, the “A” weighting is used which represents the sensitivity of an average human ear, based on the hearing ability of a young adult. Other weighting scales (B and C) are available but are not often used.

Essentially, a weighting of C is the same as the Sound Pressure Level itself. The designation of the weighting scale used is indicated following the decibel symbol e.g. weighting scale A is indicated as dBA.

Sound Pressure Level (SPL)

Twenty times the logarithm to the base 10 of the ratio of the pressure of a sound to the reference sound pressure of 20 micro Pascals (mPa), expressed as an rms value. The unit is decibel (dB). See also Sound Level.

Spouts

The insulator/bushing system at the back of the circuit breaker compartment in drawout switchgear, which allow the main (primary) connections of the circuit breaker to be plugged into the bus system (the main bus on one connection, the feeder bus on the other). Sometimes referred to as the primary disconnects. See also Bushing.

Station Ground

A ground grid or any equivalent system of grounding electrodes buried beneath or adjacent to a substation that determines the rise of ground voltage level relative to remote earth and controls the distribution of voltage gradients within the substation during a fault.

The characteristics of the Station Ground are linked to the type, shape, number and composition of the ground electrodes, the type of soil, the moisture content of the soil etc.

Stationary Contact

A conducting part having a contact surface that remains substantially stationary during use.

Strike Distance
The shortest distance measured through the insulating medium between parts of different polarities. These parts may be conducting or insulating. The insulating medium is commonly air, but could be oil or SF6 etc. See also Creepage Distance.

Sulphur Hexaflouride (SF6)

See SF6.

SF6 Circuit Breaker

A circuit breaker that uses SF6 gas for its interrupting method. See also Circuit Breaker.

Supervisory Control and Data Acquisition (SCADA)

See SCADA.

Surge Arrester

A device used to limit the severity of a voltage surge in a power system. In its simplest form, it could be a spark gap, however a more repeatable (and less stress-inducing) method is preferred. The first modern style of surge arrester used silicon carbide (SiC) discs in series with a small spark gap.

When the voltage became too high, the spark gap flashed over and the SiC discs conducted and absorbed excess energy due to their inverse resistance (as the voltage across them increased, their resistance decreases).

In the early 1980’s, modern zinc oxide (ZnO) discs were introduced and as have such an extreme inverse characteristic, no spark gap is usually required. ZnO surge arresters are sometimes referred to as “metal-oxide” type.

Switchboard

A type of switchgear assembly that consists of one or more panels with electric devices mounted thereon, and an associated framework.

Switchgear

A general term which covers switching and interrupting devices and their combination with associated control, metering, protective and regulating devices.

Also, assemblies of these devices with their associated interconnections, accessories, enclosures and supporting structures used primarily in connection with the generation, transmission, distribution and conversion of electric power.

Switchgear Assembly

An assembled piece of equipment used indoors or outdoors, including one or more of the following : switching, interrupting, control, metering, protective, regulating etc. devices, together with their supporting structures, enclosures, conductors, electrical interconnections and accessories.

Switching Device (Switch)

A device designed to close or open or both, one or more electric circuits. It must be able to open or close its rated continuous load current, but note that the ability to do the same for fault currents is not part of the basic definition.

Synthetic Test

A test in which the major part of, or the total current is obtained from one source and the major part of, or all of the transient recovery voltage is obtained from a separate source.
Telecontrol

The transmission of control signals to or from a remote apparatus using telecommunications techniques.

Telemetering

The transmission of measurable quantities to or from a remote apparatus using telecommunication techniques.

Terminal Fault

A fault directly on or very close (a few meters) to the terminals of the circuit switching device. While the impedance to the fault is very low, and the fault current is the highest in magnitude, this may actually not be the most severe interrupting duty the switching device will see. See also Short Line Fault.

Test Cabinet

In terms of a switchgear assembly, a cabinet containing permanent electric connections with cable connections to a contact box arranged to make connections to the secondary contacts on an electrically operated and removable element, which permits operation and testing of the removable element when it is removed from the housing.

Test Position (of a Circuit Breaker)

That position in which the primary disconnecting devices of the removable element are separated by a safe distance from the stationary contact elements, and some or all of the secondary circuits are in operating contact.

The test position may be the same physical position of the removable element as the disconnected position, just with the secondary circuits not connected. See also Connected Position, Disconnected Position.

Tie Feeder

A feeder that connects together two or more independent sources of power and has no tapped load between the terminals.

Time Dial

Used in association with a relay, an adjustable graduated element by which, under fixed input conditions, the prescribed relay operating time can be varied.

Total Asymmetrical Current

The combination of the AC symmetrical component and the DC component of the current.

Transfer Scheme

Equipment that (usually) automatically transfers a load to another source of power when the original source to which it has been connected fails, and that (usually) automatically restores the load to the original source under desired conditions.

Transfer Switch

A switch or switches arranged to permit transferring a conductor connection from one circuit to another without interrupting the current.

Transient Inrush Current

The current that results when a switching device is closed to energize a capacitive or inductive circuit. The current is usually characterized by its highest peak value and its frequency in Hz.
Transient Overvoltage

The voltage which occurs during the transient conditions resulting from the operation of a switching device. The voltage is expressed as the peak.

Transient Recovery Voltage (TRV)

The voltage transient that occurs across the terminals of a pole of a switching device when the current is interrupted. In a multiple pole switching device, the term is usually applied to the voltage across the first pole to interrupt.

Transition Cell

A cell supplied in a switchgear assembly used to physically transition the bus coming in a specific location or phasing on one side of the cell to the different bus location or phasing leaving the other side of the cell.

Trip-free

The capability of a switching device to have the moving contacts return to and remain in the open position when the open operation is initiated after the initiation of the closing operation, even if the closing force and the opening command are maintained.

It may be necessary for the contacts to momentarily reach the closed condition.

Trip-free Relay

An auxiliary relay whose function is to open the closing circuit of an electrically operated switching device so that the opening operation can prevail over the closing operation.

TOC

Truck Operated Contacts. A set of auxiliary contacts which are operated by the action of the truck of the removable switching device changing physical position within the cell i.e. moving between the connected and disconnected positions.

Truck

The mechanical structure which supports the operating mechanism and the current interruption components, the wheels or side rollers, and some of the required mechanical interlocks, for a removable device such as a circuit breaker.

Type Tests

See Design Tests.

Undervoltage Release

A type of circuit breaker tripping release which is held energized during normal operation, with the tripping action being caused with the removal of the voltage. Not as common in North America as the Shunt Release. See also Shunt Release.

Unit Substation

A close-coupled arrangement consisting of one or more medium voltage service entrance cells of switchgear (usually metal-enclosed type), a transformer (dry or liquid), and a line-up of typically low voltage (but perhaps medium voltage) switchgear with feeder cells.
Close coupled means that the MV service entrance switchgear is bolted directly to the transformer which is bolted directly to the LV (or MV) switchgear. If the transformer is cable connected or remote, then by definition it is NOT a unit substation.

**Vacuum Circuit Breaker**

A circuit breaker which uses a vacuum bottle for its interrupting method. See Circuit Breaker.

**Voltage Transformer**

A transformer specially designed to accurately represent the primary voltage in a secondary circuit.

Typically in North America, voltage transformers are standardized to output 120 volts when rated voltage is impressed on the primary circuit, although other values are possible. Voltage transformers can be used to power metering devices, or provide control power.

Some users still use the previous term, Potential Transformer, however the term Voltage Transformer is the correct one.

**Withstand Voltage**

The specified voltage that can be applied to insulation under specified conditions without causing flashover of puncture to occur.

**Zone of Protection**

That segment of a power system in which the occurrence of assigned abnormal conditions should cause the protective relay system to operate.
ANSI Codes – Device Designation Numbers

In the design of electrical power systems, the ANSI Standard Device Numbers (ANSI /IEEE Standard C37.2) denote what features a protective device supports (such as a relay or circuit breaker). These types of devices protect electrical systems and components from damage when an unwanted event occurs, such as an electrical fault. Device numbers are used to identify the functions of devices shown on a schematic diagram. Function descriptions are given in the standard. ANSI/IEEE C37.2-2008 is one of a continuing series of revisions of the standard, which originated in 1928.

Device Numbers

1. MASTER ELEMENT

is the initiating device, such as a control switch, voltage relay, float switch, etc., which serves either directly or through such permissive devices as protective and time-delay relays to place an equipment in or out of operation.

2. TIME DELAY STARTING OR CLOSING RELAY

is a device that functions to give a desired amount of time delay before or after any point of operation in switching sequence or protective relay system, except as specifically provided by service function 48, 62, and 79.

3. CHECKING OR INTERLOCKING RELAY

is a relay that operates in response to the position of a number of other devices (or to a number of predetermined conditions) in an equipment, to allow an operating sequence to proceed, or to stop, or to provide a check of the position of these devices or of these conditions for any purpose.

4. MASTER CONTACTOR

is a device generally controlled by device function 1 or the equivalent and the required permissive and protective devices, that serves to make and break the necessary control circuits to place an equipment into operation under the desired conditions and to take it out of operation under other or abnormal conditions.

5. STOPPING DEVICE

is a control device used primarily to shut down an equipment and hold it out of operation. (This device may be manually or electrically actuated, but excludes the function of electrical lockout [see device function 86] on abnormal conditions.)

6. STARTING CIRCUIT BREAKER

is a device whose principal function is to connect a machine to its source of starting voltage.
7. ANODE CIRCUIT BREAKER

is a device used in the anode circuits of a power rectifier for the primary purpose of interrupting the rectifier circuit if an arc-back should occur.

8. CONTROL POWER DISCONNECTING DEVICE

is a disconnecting device, such as a knife switch, circuit breaker, or pull-out fuse block, used for the purpose of respectively connecting and disconnecting the source of control power to and from the control bus or equipment.

Note: control power is considered to include auxiliary power which supplies such apparatus as small motors and heaters.

9. REVERSING DEVICE

is a device that is used for the purpose of reversing a machine field or for performing any other reversing functions.

10. UNIT SEQUENCE SWITCH

is a switch that is used to change the sequence in which units may be placed in and out of service in multiple-unit equipments.

11. RESERVED FOR FUTURE APPLICATION

(USBR assigned – Control Power Transformer).

12. OVER-SPEED DEVICE

is usually a direct-connected speed switch which functions on machine over-speed.

13. SYNCHRONOUS-SPEED DEVICE

is a device such as a centrifugal switch, a slip-frequency relay, a voltage relay, and undercurrent relay, or any type of device that operates at approximately the synchronous speed of a machine.

14. UNDER-SPEED DEVICE

is a device that functions when the speed of a machine fall below a pre-determined value.

15. SPEED OR FREQUENCY MATCHING DEVICE

is a device that functions to match and hold the speed or frequency of a machine or of a system equal to, or approximately equal to, that of another machine, source, or system.

16. RESERVED FOR FUTURE APPLICATION

(USBR assigned – Battery Charging Device).
17. SHUNTING OR DISCHARGE SWITCH

is a switch that serves to open or to close a shunting circuit around any piece of apparatus (except a resistor, such as a machine field, a machine armature, a capacitor, or a reactor).

Note: This excludes devices that perform such shunting operations as may be necessary in the process of starting a machine by devices 6 or 42, or their equivalent, and also excludes device function 73 that serves for the switching of resistors.

18. ACCELERATING OR DECELERATING DEVICE

is a device that is used to close or to cause the closing of circuits which are used to increase or decrease the speed of a machine.

19. STARTING-TO-RUNNING TRANSITION CONTACTOR

is a device that operates to initiate or cause the automatic transfer of a machine from the starting to the running power connection.

20. VALVE

is one used in a vacuum, air, gas, oil, or similar line, when it is electrically operated or has electrical accessories such as auxiliary switches.

21. DISTANCE RELAY

is a relay that functions when the circuit admittance, impedance, or reactance increases or decreases beyond predetermined limits.

22. EQUALIZER CIRCUIT BREAKER

is a breaker that serves to control or to make and break the equalizer or the current-balancing connections for a machine field, or for regulating equipment in a multiple-unit installation.

23. TEMPERATURE CONTROL DEVICE

is a device that function to raise or lower the temperature of a machine or other apparatus, or of any medium, when its temperature falls below, or rises above, a predetermined value.

Note: An example is a thermostat that switches on a space heater in a switchgear assembly when the temperature falls to a desired value as distinguished from a device that is used to provide automatic temperature regulation between close limits and would be designated as device function 90T.

24. RESERVED FOR FUTURE APPLICATION

(USBR assigned – bus tie circuit breaker, contactor, or switch.)

25. SYNCHRONIZING OR SYNCHRONISM-CHECK DEVICE

is a device that operates when two a-c circuits are within the desired limits of frequency, phase angle, or voltage, to permit or to cause the paralleling of these two circuits.
26. APPARATUS THERMAL DEVICE
is a device that functions when the temperature of the shunt field or the amortisseur winding of a machine, or that of a load limiting or load shifting resistor or of a liquid or other medium, exceeds a predetermined value: or if the temperature of the protected apparatus, such as a power rectifier, or of any medium decrease below a predetermined value.

27. UNDERSHOT DEVICE
is a device that functions on a given value of under-voltage.

28. FLAME DETECTOR
is a device that monitors the presence of the pilot or main flame of such apparatus as a gas turbine or a steam boiler.

29. ISOLATING CONTACTOR
is a device that is used expressly for disconnecting one circuit from another for the purposes of emergency operation, maintenance, or test.

30. ANNUNCIATOR RELAY
is a non-automatically reset device that gives a number of separate visual indications of the functions of protective devices, and which may also be arranged to perform a lockout function.

31. SEPARATE EXCITATION DEVICE
is a device that connects a circuit, such as the shunt field of a synchronous converter, to a source of separate excitation during the starting sequence; or one that energizes the excitation and ignition circuits of a power rectifier.

32. DIRECTIONAL POWER RELAY
is a device that functions on a desired value of power flow in a given direction or upon reverse power resulting from arcback in the anode or cathode circuits of a power rectifier.

33. POSITION SWITCH
is a switch that makes or breaks contact when the main device or piece of apparatus which has no device function number reaches a given position.

34. MASTER SEQUENCE DEVICE
is a device such as a motor-operated multi-contact switch, or the equivalent, or programming device, such as a computer, that establishes or determines the operating sequence of the major devices in a equipment during starting and stopping or during other sequential switch operations.

35. BRUSH-OPERATING OR SLIPPING SHORT-CIRCUITING DEVICE
is a device for raising, lowering, or shifting the brushes of a machine, or for short-circuiting its slip rings, or for engaging or disengaging the contacts of a mechanical rectifier.
36. **Polarity or Polarizing Voltage Device**

is a device that operates, or permits the operation of, another device on a predetermined polarity only, or verifies the presence of a polarizing voltage in an equipment.

37. **Undercurrent or Underpower Relay**

is a relay that function when the current or power flow decreases below a predetermined value.

38. **Bearing Protective Device**

is a device that functions on excessive bearing temperature, or on another abnormal mechanical conditions associated with the bearing, such as undue wear, which may eventually result in excessive bearing temperature.

39. **Mechanical Condition Monitor**

is a device that functions upon the occurrence of an abnormal mechanical condition (except that associated with bearing as covered under device function 38), such as excessive vibration, eccentricity, expansion shock, tilting, or seal failure.

40. **Field Relay**

is a relay that functions on a given or abnormally low value or failure of a machine field current, or on excessive value of the reactive component of armature current in an a-c machine indicating abnormally low field excitation.

41. **Field Circuit Breaker**

is a device that functions to apply or remove the field excitation of a machine.

42. **Running Circuit Breaker**

is a device whose principal function is to connect a machine to its source of running or operation voltage. This function may also be used for a device, such as a contactor, that is used in series with a circuit breaker or other field protecting means, primarily for frequent opening and closing of the breaker.

43. **Manual Transfer or Selector Device**

is a manually operated device that transfers the control circuits in order to modify the plan of operation of the switching equipment or of some of the devices.

44. **Unit Sequence Starting Relay**

is a relay that function to start the next available unit in a multiple-unitequipment upon the failure or non-availability of the normally preceding unit.

45. **Atmospheric Condition Monitor**

is a device, that functions upon the occurrence of an abnormal atmospheric condition, such as damaging fumes, explosive mixtures, smoke or fire.
46. REVERSE PHASE OR PHASE BALANCE CURRENT RELAY

is a relay that functions when the polyphase currents are of reverse-phase sequence, or when the polyphase currents are unbalanced or contain negative phase-sequence components above a given amount.

47. PHASE-SEQUENCE VOLTAGE RELAY

is a relay that function upon a predetermined value of polyphase voltage in the desired phase sequence.

48. INCOMPLETE SEQUENCE RELAY

is a relay that generally returns the equipment to the normal, or off, position and locks it out if the normal starting, operating, or stopping sequence is not properly completed within a predetermined time. If the device is used for alarm purposes only, it should preferably be designated as 48A (alarm).

49. MACHINE OR Transformer THERMAL RELAY

is a relay that functions when the temperature of a machine armature or other load-carrying winding or element of a machine or the temperature of a power rectifier or power transformer (including a power rectifier transformer) exceeds a predetermined value.

50. INSTANTANEOUS OVERCURRENT OR RATE-OF-RISE RELAY

is a relay that functions instantaneously on an excessive value of current or on an excessive rate of current rise, thus indicating a fault in the apparatus or circuit being protected.

51. A-C TIME OVERCURRENT RELAY

is a relay with either a definite or inverse time characteristic that functions when the current in an a-c circuit exceed a predetermined value.

52. A-C CIRCUIT BREAKER

is a device that is used to close and interrupt an a-c power circuit under normal conditions or to interrupt this circuit under fault of emergency conditions.

53. EXCITER OR D-C GENERATOR RELAY

is a relay that forces the d-c machine field excitation to build up during starting or which functions when the machine voltage has been built up to a given value.

54. HIGH-SPEED D-C CIRCUIT BREAKER

is a circuit breaker which starts to reduce the current in the main circuit in 0.01 second or less, after the occurrence of the d-c overcurrent or the excessive rate of current rise.

55. POWER FACTOR RELAY

is a relay that operates when the power factor in an a-c circuit rises above or falls below a predetermined value.
56. FIELD APPLICATION RELAY

is a relay that automatically controls the application of the field excitation to an a-c motor at some predetermined point in the slip cycle.

57. SHORT-CIRCUITING OR GROUNDING DEVICE

is a primary circuit switching device that functions to short-circuit or to ground a circuit in response to automatic or manual means.

58. RECTIFICATION FAILURE RELAY

is a device that functions if one or more anodes of a power rectifier fail to fire, or to detect and arc-back or on failure of a diode to conduct or lock properly.

59. OVERVOLTAGE RELAY

is a relay that functions on a given value of over-voltage.

60. VOLTAGE OR CURRENT BALANCE RELAY

is a relay that operates on a given difference in voltage, or current input or output, or two circuits.

61. RESERVED FOR FUTURE APPLICATION.

62. TIME-DELAY STOPPING OR OPENING RELAY

is a time-delay relay that serves in conjunction with the device that initiates the shutdown, stopping, or opening operation in an automatic sequence or protective relay system.

63. LIQUID OR GAS PRESSURE OR VACUUM RELAY

is a relay that operates on given values of liquid or gas pressure or on given rates of change of these values.

64. GROUND PROTECTIVE RELAY

is a relay that functions on failure of the insulation of a machine, transformer, or of other apparatus to ground, or on flashover of a d-c machine to ground.

**Note:** This function is assigned only to a relay that detects the flow of current from the frame of a machine or enclosing case or structure of piece of apparatus to ground, or detects a ground on a normally ungrounded winding or circuit. It is not applied to a device connected in the secondary circuit of current transformer, in the secondary neutral of current transformers, connected in the power circuit of a normally grounded system.

65. GOVERNOR

is the assembly of fluid, electrical, or mechanical control equipment used for regulating the flow of water, steam, or other medium to the prime mover for such purposes as starting, holding speed or load, or stopping.
66. NOTCHING OR JOGGING DEVICE

is a device that functions to allow only a specified number of operations of a given device or equipment, or a specified number of successive operations within a given time of each other. It is also a device that functions to energize a circuit periodically or for fractions of specified time intervals, or that is used to permit intermittent acceleration or jogging of a machine at low speeds for mechanical positioning.

67. A-C DIRECTIONAL OVERCURRENT RELAY

is a relay that functions on a desired value of a-c over-current flowing in a predetermined direction.

68. BLOCKING RELAY

is a relay that initiates a pilot signal for blocking of tripping on external faults in a transmission line or in other apparatus under predetermined condition, or cooperates with other devices to block tripping or to block re-closing on an out-of-step condition or on power savings.

69. PERMISSIVE CONTROL DEVICE

is generally a two-position, manually-operated switch that, in one position, permits the closing of a circuit breaker, or the placing of an equipment into operation, an in the other position prevents the circuit breaker or the equipment from being operated.

70. RHEOSTAT

is a variable resistance device used in an electric circuit, which is electrically operated or has other electrical accessories, such as auxiliary, position, or limit switches.

71. LIQUID OR GAS-LEVEL RELAY

is a relay that operates on given values of liquid or gas level or on given rates of change of these values.

72. D-C CIRCUIT BREAKER

is a circuit breaker that is used to close and interrupt a d-c power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions.

73. LOAD-RESISTOR CONTACTOR

is a contactor that is used to shunt or insert a step of load limiting, shifting, or indicating resistance in a power circuit, or to switch a space heater in circuit, or to switch a light or regenerative load resistor, a power rectifier, or other machine in and out of circuit.

74. ALARM RELAY

is a relay other than an annunciator, as covered under device function 30, that is used to operate, or to operate in connection with, a visual or audible alarm.
75. POSITION CHANGING MECHANISM

is a mechanism that is used for moving a main device from one position to another in an equipment: as for example, shifting a removable circuit breaker unit to and from the connected, disconnected, and test positions.

76. D-C OVERCURRENT RELAY

is a relay that function when the current in a d-c circuit exceeds a given value.

77. PULSE TRANSMITTER

is used to generate and transmit pulses over a telemetering or pilot-wire circuit to the remote indicating or receiving device.

78. PHASE-ANGLE MEASURING OR OUT-OF-STEP PROTECTIVE RELAY

is a relay that functions at a pre-determined phase angle between two voltages or between two currents or between a voltage and current.

79. A-C RECLOSING RELAY

is a relay that controls the automatic reclosing and locking out of an a-c circuit interrupter.

80. LIQUID OR GAS FLOW RELAY

is a relay that operates on given values of liquid or gas flow or on given rates of change of these values.

81. FREQUENCY RELAY

is a relay that functions on a predetermined value of frequency (either under or over or on normal system frequency) or rate of change of frequency.

82. D-C RECLOSING RELAY

is a relay that controls the automatic closing and re-closing of a d-c circuit interrupter, generally in response to load circuit conditions.

83. AUTOMATIC SELECTIVE CONTROL OR TRANSFER RELAY

is a relay that operates to select automatically between certain sources or conditions in a equipment, or performs a transfer operation automatically.

84. OPERATING MECHANISM

is the complete electrical mechanism or servomechanism, including the operating motor, solenoids, position switches, etc., for a tap changer, induction regulator, or any similar piece of apparatus which otherwise has no device function number.
85. CARRIER OR PILOT-WIRE RECEIVER RELAY

is a relay that is operated or restrained by a signal used in connection with carrier-current or d-c pilot-wire fault directional relaying.

86. LOCKING-OUT RELAY

is an electrically operated hand, or electrically reset relay or device that functions to shut down or hold an equipment out of service, or both, upon the occurrence of abnormal conditions.

87. DIFFERENTIAL PROTECTIVE RELAY

is a protective relay that functions on a percentage or phase angle or other quantitative difference of two currents or of some other electrical quantities.

88. AUXILIARY MOTOR OR MOTOR GENERATOR

is one used for operating auxiliary equipment, such as pumps, blowers, exciters, rotating magnetic amplifiers, etc.

89. LINE SWITCH

is a switch used as a disconnecting, load-interrupter, or isolating switch in an a-c or d-c power circuit, when this device is electrically operated or has electrical accessories, such as an auxiliary switch, magnetic lock, etc.

90. REGULATING DEVICE

is a device that functions to regulate a quantity, or quantities, such as voltage, current power, speed, frequency, temperature, and load at a certain value or between certain (generally close) limits for machines, tie lines, or other apparatus.

91. VOLTAGE DIRECTIONAL RELAY

is a device which operates when the voltage across an open circuit breaker or contactor exceeds a given value in a given direction.

92. VOLTAGE AND POWER DIRECTIONAL RELAY

is a relay that permits or causes the connection of two circuits when the voltage difference between them exceed a given value in a predetermined direction and causes these two circuits to be disconnected from each other when the power flowing between them exceeds a given value in the opposite direction.

93. FIELD-CHANGING CONTACTOR

is a contactor that functions to increase or decrease, in one step, the value of field excitation on a machine.

94. TRIPPING OR TRIP-FREE RELAY

is a relay that function to trip a circuit breaker, contactor or equipment, or to permit immediate tripping by other devices; or to prevent immediate re-closure of a circuit interrupter if it should open automatically even though its closing circuit is maintained closed.
95.* (USBR ASSIGNED – CLOSING RELAY OR CONTACTER)

96.*

97.*

98.* (USBR ASSIGNED – LOSS OF EXCITATION RELAY)

99.* (USBR ASSIGNED – ARC DETECTOR)

* Used only for specific applications in individual installations where none of the assigned numbered functions from 1 to 94 are suitable.

Auxiliary Devices

These letters denote separate auxiliary devices, such as:

- **C** – Closing Relay or Contactor
- **CL** – Auxiliary Relay, Closed (energized when main device is in closed position).
- **CS** – Control Switch
- **D** – “Down” Position Switch or Relay
- **L** – Lowering Relay
- **1.** – Opening Relay
- **OP** – Auxiliary Relay, Open (energized when main device is in open position).
- **PB** – Push Button
- **R** – Raising Relay
- **U** – “Up” Position Switch or Relay
- **X** – Auxiliary Relay
- **Y** – Auxiliary Relay
- **Z** – Auxiliary Relay

**Note:** In the control of a circuit breaker with an X-Y Relay Control Scheme, the X relay is the device whose main contacts are used to energized the closing coil or the device which in some other manner, such as by the release of stored energy, causes the breaker to close. The contacts of the Y relay provide the anti-pump feature for the circuit breaker.
What is ANSI code for Antipumping relay?

ANSI codes 94 or even 52 can be used.

How relays are classified based on functional categories?

Relays can be divided into six functional categories shown below:

Protective relays

Detect defective lines, defective apparatus, or other dangerous or intolerable conditions. These relays generally trip one or more circuit breaker, but may also be used to sound an alarm.

Monitoring relays

Verify conditions on the power system or in the protection system. These relays include fault detectors, alarm units, channel monitoring relays, synchronism verification, and network phasing. Power system conditions that do not involve opening circuit breakers during faults can be monitored by verification relays.

Reclosing relays

Establish a closing sequence for a circuit breaker following tripping by protective relays. Regulating relays are activated when an operating parameter deviates from predetermined limits. Regulating relays function through supplementary equipment to restore the quantity to the prescribed limits.

Auxiliary relays

Operate in response to the opening or closing of the operating circuit to supplement another relay or device. These include timers, contact-multiplier relays, sealing units, isolating relays, lockout relays, closing relays, and trip relays.

Synchronizing (or synchronism check) relays

Assure that proper conditions exist for interconnecting two sections of a power system.
Many modern relays contain several varieties of these functions. In addition to these functional categories, relays may be classified by input, operating principle or structure, and performance characteristic.

The following are some of the classifications and definitions described in ANSI/IEEE Standard C37.90 (also ANSI/IEEE C37.100 “Definitions for Power Switchgear”):

**Inputs**
- Current
- Voltage
- Power
- Pressure
- Frequency
- Temperature
- Flow
- Vibration

**Operating Principle or Structures**
- Current balance
- Percentage
- Multirestraint
- Product
- Solid state
- Static
- Microprocessor
- Electromechanical
- Thermal

**Performance Characteristics**
- Differential
- Distance
- Directional over current
- Inverse time
- Definite time
- Under voltage
- Over voltage
- Ground or phase
- High or low speed
- Pilot
- Phase comparison
- Directional comparison
- Current differential

**Solid-state (and static) relays** are further categorized under one of the following designations:

**Analog**

Analog relays are those in which the measured quantities are converted into lower voltage but similar signals, which are then combined or compared directly to reference values in level detectors to produce the desired output (e.g., SA-1 SOQ, SI-T, LCB, circuit shield relays).

**Digital**
Digital relays are those in which the measured ac quantities are manipulated in analog form and subsequently converted into square-wave (binary) voltages. Logic circuits or microprocessors compare the phase relationships of the square waves to make a trip decision.

Numerical

Numerical relays are those in which the measured ac quantities are sequentially sampled and converted into numeric data form. A microprocessor performs mathematical and/or logical operations on the data to make trip decisions.

How do we classify an Antipumping relay?

It is classified as an auxiliary relay.

Why Antipumping relay is used?

Anti pumping relaying is done primarily to indicate the spring failure of TNC switch and a person need to attend the problem. The function of this relay is to cut off the supply to 52C (CB closing coil) in case of TNC switch spring failure and prevent CB hunting effect (i.e. continuous closing, opening operation).

Anti pumping is also called trip free mechanism of any circuit breaker. Suppose the breaker has been instructed to close by manual instruction by pressing the TNC (trip neutral close push button) switch. The operating mechanism will start operating for closing operation.

Meanwhile a fault has taken place and relay closes the trip circuit of breaker. The trip free mechanism/ Anti pumping feature permits the circuit breaker to be tripped by protective relay even if it is under process of closing. Thus auxiliary relay (or sometimes the inbuilt feature of circuit breaker) which prevent alternate tripping and closing of the circuit breaker if closing push button is held close during fault is called the trip free mechanism or anti pumping mechanism.

What will happen if Antipumping relay circuit is not present?

If the circuit breaker is closed using TNC switch, and at the same instant let spring of TNC switch has failed and it did not came to its neutral state, and primary protection relay had been operated at this instant and opened the CB, since supply is being extended to 52C (CB closing coil) because of TNC spring failure, then CB will close again, since fault is still persisting the following cycle occurs.

CB trip, because of protection. Operation -> CB close, because of TNC switch spring failure-> CB trip, because of protection. Operation-> CB close, because of TNC switch spring failure-> CB trip, because of protection. Operation -> CB close, because of TNC switch spring.

The above cycle is termed as circuit breaker hunting. Circuit breaker hunting will cause damage to breaker and it can be avoided by using 52 (Circuit breaker Antipumping relay). The function of this relay is to cut off the supply to 52C (CB closing coil) coil in case of TNC switch spring failure and prevent CB hunting effect (i.e. continuous closing, opening operation).

Let us analyse the behavior of circuit in case anti pumping is present and in case it is not present, one by one:
CASE 1: Closing Coil Circuit Without 52 Relay

The path for CB close without 52 relay is shown in Figure 1. In this case if spring of TNC switch fails, then supply will be get extended to 52C (CB closing coil) coil as shown in Figure 2.

![Figure 1 - Circuit breaker closing coil without Antipumping relay](image1)

If the TNC switch spring has failed then supply will be extended as shown below.

![Figure 2 - showing how supply will be extended to closing coil because of TNC spring failure](image2)

CASE 2: Closing Coil Circuit With 52 Relay

Closing coil circuit with 52 present is as shown in Figure 3. Path 1 in Figure 3 shows how 52C (CB closing coil) will be energized when we press TNC switch CS1. If CS1 comes to its original state once we release it then 52 will not come in picture. If CS1 does not come to its original state then 52 will be energized as shown in path 2. Then 52-NC contact present in path 1 will be got opened up and prevents extension of supply.

We have the concept that initially for the energization of 52 80% to 90% of 110V is required. But once after energization 60-70% of 110V is sufficient to maintain its energization state. This logic is achieved by introducing a resistance in 52 energization maintenance path. This path is shown in Figure 4.
Once 52 is energized it will give an alarm and a maintenance person in the substation need to attend that problem. This is how 52 is useful in avoiding CB hunting effect.

What is ANSI code for Master trip lockout relay?

ANSI code 86 is used.

What is function & Utility of lockout relay?

When a “drive-to-lockout” input is energized, the reclosing relay will go into lockout from any point in the sequence. The relay will stay in lockout until the input is removed and the breaker is closed manually or by supervisory control. Upon removal, the recloser will go through its reset sequence and return to “ready” state.
All the different trip signals from fault detection devices are wired to the lockout relay, which is the master trip relay for the circuit breaker. It is usually a manually reset relay with an indicating flag or lamp. In case of DG a similar philosophy of tripping is used in the engine control panel in which all the mechanical failure signals are received at the engine lockout relay (86-T, T for turbine). This lockout relay also trips the generator circuit breaker.

When either the 86-G or the 86-T relay sends its signal to the circuit-breaker trip coil, time is taken before the circuit breaker begins to move and finally reach its fully open state. The generator switchgear is recommended to have two separate lockout relays. One will receive all the electrical protection relay trip signals, and denoted as 86–1. The other will receive a master trip signal (or several trip signals) from the turbine unit control panel, and denoted as 86–2.

It operates whenever any of the protection relay operates and would prevent any circuit breaker operation until the lock out relay is manually rest.

Can we manage without anti pumping since operation of lock out relay would prevent any further operations of CB even continuous opening-closing?

+Ve

-Ve

Hand Reset Lockout Relay Contact

Figure 5 - Antipumping relay & Lockout relay contacts in closing coil circuit

Let us assume that we have closed the circuit breaker using the TNC switch CS1. At this instant TNC switch spring failed and fault is there which is sensed by primary protection relay and sends tripping command to circuit breaker. This would energize the trip coil of breaker; this will result in operation of lock out relay.

The lock out relay will go into lock out state as shown in Figure 6 below:
Now let a person had attended that fault and reseted 86 lockout contacts. After resetting its status will be NC and a closed command will be extended to closing coil without any human interface which is a mal function.

**So an 86 lockout relay cannot fulfill the purpose of anti pumping relay.**

The function of anti pumping relay is to cut off the supply to closing coil in case of TNC switch spring failure and prevent CB hunting effect (i.e. continuous closing, opening operation) and a person needs to attend the problem. Where as 86 lock out relay contact in closing circuit is meant to ensure that a person had attended the fault occurred and we are closing the circuit after clearing the circuit.

It is extra mechanical protection meant for safety of equipments considering the cost and sophistication involved; it is always advisable to go for extra human interface.

**REFERENCES:**

1. ANSI/IEEE C37.100 “Definitions for Power Switchgear”.
2. Relay And Circuit-Breaker Application Authors: E. L. Harder and J. C. Cunningham.

**Ionization (corona discharge) tests**
The ionization test is used primarily for detecting ionization (corona discharge) and slot discharge in generator windings. Both ionization and slot discharge may cause deterioration of insulation. Ionization generally occurs in voids inside the insulation within the ground shield section of the coil. Some internal ionization is present in most higher voltage stator insulation. If it is intense enough, it produces destruction of the binder and other organic components by the chemical effects of the ozone and oxides of nitrogen generated by the discharge (plus moisture) and eventually by direct electronic bombardment. Destruction is often aggravated finally by mechanical vibration of the conductors where the insulation has been softened by the other effects. Slot discharge is a capacitance discharge and occurs across poor contact points between the coil surface shielding and the stator iron. Deterioration is from the destructive effect of this relatively concentrated discharge. Coils which fit loosely in the slots may be subjected to this trouble.

Test apparatus for corona detection requires much higher sensitivity than detection of slot discharge.

Test Methods for Slot Discharge

A method used for detecting slot discharge in AC generator windings consists of energizing the winding from a high-potential AC test set at voltages of approximately 50 to 125 percent of normal rated machine voltage or running the unit self excited and isolated from the system and observing on an oscilloscope the resulting induced potentials from slot discharges. The detecting apparatus is essentially a band pass filter passing a band of frequencies between 1,000 and 2,000 Hz to an oscilloscope. The detecting apparatus is coupled through a condenser to the terminal of the winding being tested or to a probe which is placed in contact with the stator coil shielding. With the oscilloscope sweep set for one-half the applied frequency, the characteristic hash indication appears at two or four places along the sweep since the discharge occurs at particular parts of the voltage cycle.

Because the detector cannot distinguish between hash originating in the winding and that originating in the power source, it is essential that the stator winding be energized from a good high-potential test set or a transformer operated well below its rated voltage. Voltage of about 50 percent, normal or below which no corona occurs, is first applied as a calibration point or base. The voltage is gradually raised until there is distinct change in the hash on the oscilloscope screen.

This is the point where slot discharge is considered to begin. A winding properly protected from slot discharge should not produce hash at voltages below approximately 125 percent of normal. Experience and special calibration apparatus are necessary in order to properly interpret the results.
Medium voltage circuit breaker operating sequence

Rated switching sequence according to IEC, O – t – CO – t’ – CO. (cf. opposite diagram):

O – Represents opening operation

CO – Represents closing operation followed immediately by an opening operation

Three rated operating sequences exist:

- **Slow**: O – 3 min – CO – 3 min – CO
- **Fast 1**: O – 0.3 s – CO – 3 min – CO
- **Fast 2**: O – 0.3 s – CO – 15 s – CO

NOTE: Other sequences can be requested from manufacturer.

Close/Open cycle

Assumption: O order as soon as the circuit breaker is closed

Automatic reclosing cycle

Assumption: C order as soon as the circuit breaker is open, (with time delay to achieve 0.3 s or 15 s or 3 min).
Closed position

Contact movement

Open position

Current flow

Dead time

Open-close time

Remake time

Reclosing time

Final arc extinction in all poles

Separation arcing contacts in all poles

Energizing of opening release

Energizing of closing circuit

Start of current in the first pole

Contact touch in all poles

Contact touch in the first pole

Time