ELECTRICAL TERMS

INTRODUCTION

This listing with associated discussion is to aid in understanding electrical terms used in other sections of this manual.

POSITION

Refer to this listing for introductory and supplemental information on electrical terms. Many electrical terms are defined in other Property Risk Consulting Guidelines and in the codes referenced by these sections, like the *National Electrical Code*® (NEC). Those definitions are not repeated in this section. For more detailed information on any term, refer to an electrical engineering handbook.

Some terms have more than one meaning. This listing presents the meaning common to use in AXA XL Risk Consulting loss prevention and control activities.

DISCUSSION

AC Hi-Pot Test: A possibly destructive test that applies higher than rated voltage stress to an electrical device. This test is not regularly scheduled, rather it is used to test insulation suspected of weakening from extreme operating or environmental conditions. It forces weak insulation to fail.

Acidity Test: A fluid dielectric test yielding the "neutralization number," which represents the number of milligrams of potassium hydroxide required to neutralize the acid contained in one gram of fluid. As oxidation causes the acidity of the fluid to increase, the number increases, and reconditioning is suggested to prevent sludge formation. This is a common test used in evaluating the condition of transformer oils.

Admittance: A vector quantity designating the relationship between voltage and current in an ac circuit. It is a ratio of phasor values, and is equal to the reciprocal of impedance (Z). Admittance (Y) is commonly shown by the formula:

$$Y = \frac{1}{Z} = \frac{I}{E}$$

where I is the steady-state current and E is the steady-state voltage. Also see **Impedance**.

Admittance also represents the vector sum of the conductance and susceptance of the system, and is expressed as a complex number:

$$Y = G + jB$$

where Y is the admittance, G is the conductance or real part of the admittance, and B is the susceptance or "imaginary" part of the admittance. Y, G, and B are all measured in mhos.

Vector sums are often shown in phasor diagrams.

Air Gap (in rotating machinery): The space between a rotor and stator that contains some gaseous dielectric. The dielectric is usually air, but the term is not meant to restrict the gas. Hydrogen is commonly used as the dielectric around the windings and in the air gaps of generators.

Ampacity: The current carrying capacity, expressed in amperes, of an electrical conductor under defined (design) conditions. The ampacity is based on thermal considerations and is affected by insulation, frequency, heat dissipation and ambient temperature.

Antenna Discharge Unit: A combination lightning arrester and static discharge device required by the NEC for use with certain communications equipment. The device has two terminals, one for connection to an antenna, the other for connection to ground. Listed devices can repeatedly discharge a specified test voltage without damage. Both fixed gap (with air in the dielectric space) and fixed resistance (a solid dielectric) type units are available.

Antipump Device: An auxiliary safety device or component that becomes energized as automatic switchgear opens, and prevents this switchgear from reclosing on demand until the antipump device is reset. Without an antipump device, opposing responses to reclosure and trip signals would cause the switchgear to continually cycle open and closed. Pumping action involving repeated reclosures into an electrical fault can greatly magnify system and property damage.

Arc: An electrical discharge through air or a gas. The energy of the discharge or arc is proportional to its current, voltage and duration. The temperature of a high-energy fault arc can be as high as 35,000°F (19,500°C), which is higher than the temperature of the sun.

A high-energy arc can vaporize metallic conductors and other conductive materials. An arc can "consume" wiring and bus, and can "cut" a hole in the metal wall of a panel enclosure.

The volume of copper expands by a factor of 67,000 as it vaporizes. In contrast, water expands by a factor of only 1670 as it becomes steam.

Initially, the heat of a high-energy arc heats the surrounding air to cause an enormous and quick temperature rise. Any rapid increase in gas temperature causes a rapid increase or expansion of its volume. The simultaneous vaporization of metal results in an almost explosive increase in gas/vapor volume.

In a confined space, an explosive increase in gas/vapor volume results in a similarly explosive increase in pressure. Such pressures have sheared bolts off enclosure covers, ruptured or exploded those enclosures, and propelled objects and shrapnel distances of 30 ft (9 m) and more.

Vaporized metal can be carried away from a fault by the initial blast of superheated air. As the metallic vapor cools, tiny molten metal droplets condense. These droplets harden into tiny, round, beads of metal. The beads, which can be too small to be seen without magnifying lenses, usually drop onto ledges and floors in a circular area around the fault.

Radiant heat and contact with hot metal droplets can cause combustibles in the vicinity of an arc to ignite. For instance, cloth made from ordinary fibers ignites at about 700°F (370°C). Cloth made from wool and similar natural fibers ignites at higher temperatures, possibly as high as 1400°F (760°C). Three approaches to preventing ignition are: increasing the distance between combustibles and electrical equipment, shortening the time that an arc can exist by using quick-acting overcurrent devices, and limiting the amount of fault or "let-through" current in a circuit.

Low energy arcs can be difficult to detect.

Fluorescent lamps and similar arcing devices contain special gases to carry low energy arcs. These gases readily break down to carry arc discharge currents between the cathodes and anodes.

Armature Winding: The machine winding designed to acquire alternating voltage by virtue of the relative motion between the winding and the magnetic flux field (the process of induction).

Automatic Circuit Recloser: A self-controlled device for interrupting, reclosing, and locking open an ac circuit. The device is usually set to make a predetermined number of attempts to reclose and latch. Continuing failures result in a lockout operation.

Auxiliary Gutter: A raceway meeting the requirements of NEC Article 374. Also called a gutter.

Average Voltage: The average value of all instantaneous absolute voltage values over a full cycle. For sine wave voltages, the average voltage is 0.637 times the peak value. Also see **rms Voltage**.

AWG: The American Wire Gauge, or Brown and Sharpe specification for wire size or gauge. In the U.S., AWG is used almost exclusively to size solid copper wire. The diameter of size 0000 (also 4/0 and 4-Nought) is chosen to be 0.4600 in. Size 36 AWG is 0.0050 in. There are 39 reductions in size between 4/0 and 36 AWG. (4/0, 3/0, 2/0, 1/0, 1, 2, 3, 4, etc.) Intermediate sizes decrease geometrically from one size to the next smaller size, by the factor:

$$\left(\frac{0.4600}{0.0050}\right)^{1/39} = 1.22932$$

Large gauges (larger than 4/0) are often sized by cross-sectional area denoted in thousand-circular-mills (kcmil or kCM), rather than by AWG. Table 1 shows dimensions for solid conductors of common AWG sizes.

TABLE 1
Wire Sizes

Gauge	Diameter		Area	
(AWG)	(in.)	(mm)	(kCM)	(mm^2)
4/0	0.4600	11.68	211.6	107
3/0	0.4096	10.40	167.8	85.0
2/0	0.3648	9.266	133.1	67.4
1/0	0.3249	8.251	105.5	53.5
1	0.2893	7.348	83.69	42.4
8	0.1285	3.264	16.51	8.37
10	0.1019	2.588	10.38	5.26
12	0.08081	2.053	6.530	3.31
14	0.06408	1.628	4.107	2.08
22	0.02535	0.6438	0.6424	0.33
36	0.0050	0.1270	0.0250	0.01

Basic Impulse Insulation Level (BIL): A voltage rating that represents the peak impulse voltage that an insulation system is designed to withstand. The rating is established for an impulse waveshape with a defined duration and rate-of-rise, thus the insulation system may fail when attempting to withstand a waveshape having the same amplitude but a dissimilar shape.

Black Start: Running an electric generator up to speed to provide power without the use of an external electric power source. Often referred to for certain power producing sites that can generate electricity to get larger sites up to speed during a grid power failure. Not all generators have black start capability. Some depend on external power sources, such as generating station power or the system grid. Black start capability means being able to start a generator when all external power systems fail. Black start power requirements are about 5% of the capacity of the unit to be started, and add about 2% to the station cost.

Bolted Through-Fault (or **Close-In Through-Fault)**: The transformer fault condition that would be expected to occur with a large capacity bus bolted across the secondary bushings creating a short, or any fault approximating that size. For the secondary side of the transformer, it is assumed to be the point of least impedance and highest current flow.

Bonding: The joining of metallic parts to form an electrically conductive path and assure electrical continuity. A bonding connection is reliable and can carry any current likely to be imposed.

Brushes: Shaped blocks of carbon compounds held against a commutator or slip rings by pressure from a spring. Carbon and graphite compounds have the best overall properties for such electrical use; however, they wear poorly, producing dust. Brushes are consumable and replaceable. Wear and breakage are not considered failures.

Buchholz Relay: Originally, a special, dual-chambered, protective relay designed to protect oil-insulated transformers when the relay is connected in series with piping joining the conservator and main transformer tank. Operation of this relay is based on two principles: gradual decomposition of the insulation system produces gases that are released into the oil; and electrical breakdown involving arcing or rapid heating produces a sudden increase in internal pressure.

The Buchholz relay is both a **gas accumulator relay** and a **sudden pressure relay** because a chamber is provided for each function. One chamber detects gassing. As oil flows through the chamber, gas bubbles rise, become trapped, and accumulate. Reaching a predetermined volume of gas activates an alarm. If operating conditions are promptly reviewed, and necessary inspections and tests are performed without significant delays, the cause of insulation deterioration can be uncovered and corrective action taken before electrical breakdown occurs.

The other chamber detects a sudden increase in oil pressure or flow, which indicates severe electrical breakdown. This sudden pressure relay initiates an immediate power disconnect by opening a circuit breaker.

The original Buchholz relays were widely used in Europe. References to beechwood relay or beech relay were the result of incorrect German translations. The name now sometimes describes devices serving similar purposes but not meeting original specifications. Some of these devices are located directly on transformer tanks. Some test the combustibility of accumulated gas. Some pass the gas over heating elements to determine gas generation rates by measuring temperature rise. Some of these devices are used on transformers containing insulating liquids other than oil. These alternative devices do not serve the original dual functions, so they are not true Buchholz relays.

Building: (as used in the NEC): A structure that either stands alone or is cut off from adjoining structures by fire walls with all openings therein protected by approved fire doors.

Bus: A conductor providing two or more points of connection for supplying separate circuits. A bus may be a wire, cable, rod, tube, strip, or plate.

Bus Bar: A bus made of a rigid, conductive strip or plate to transmit large currents. Bus bars may be copper or aluminum. Copper bus bars may be silver-plated to prevent corrosion on high temperature surfaces, such as joints between sections of bus duct and takeoffs of plug-in bus ducts. Contacting surfaces of aluminum bars are usually plated, first with a layer of copper, then with a layer of tin or silver. Bars may be supported by molded plastic, fiberglass-impregnated plastic, or porcelain insulators.

Bushing: An insulating structure through which an electrical conductor passes as it traverses from one side of a barrier to another, e.g., through a transformer tank wall. The bushing is attached to a barrier so that the exposed conductor at both ends is electrically remote from the barrier, preventing insulation breakdown including flashover.

Busway: A grounded metal enclosure containing factory mounted bus and meeting the requirements of NEC Article 364. The conductors may be bare or insulated, and are usually copper or aluminum bars, rods or tubes.

Bypass Isolation Switch: A manually operated switching device used in conjunction with a transfer switch to provide a means of directly connecting a load to a power source, and of disconnecting

(bypassing) the transfer switch. This bypass isolation switch allows the transfer switch to be tested, and if it has drawout capability, removed for inspection, without interrupting power to the load.

Cabinet: A surface- or flush-mounted enclosure, usually with swinging doors, to contain electrical wiring and devices.

Cablebus: An assembly of enclosed insulated cables meeting the requirements of NEC Article 365.

Cable Size: Cable gauge. Also see **AWG**.

Cable Tray: A rigid ladder, trough, channel, solid-bottomed tray or other raceway meeting the requirements of NEC Article 318. The NEC prohibits single-conductor cable less than 1/0 size in a cable tray.

Cellular Floor Raceway: A raceway consisting of hollow spaces within a floor member or slab, and conforming to NEC Article 356 or 358.

Circuit Breaker: A mechanical switching device connecting an electric power source to a load, and designed to open and close the circuit under load conditions. Like a fuse, it forms a protected circuit, automatically opening the circuit upon predetermined abnormal circuit conditions. Actuation can be by integral components, or by a signal from a protective relay in a control circuit. Unlike a fuse, a circuit breaker does not destroy itself when opening a circuit, as long as it is properly applied within its rating. Circuit breakers are designed for infrequent operation only, and may require servicing before manual reclosure. High voltage breakers are rated at or above 1000 V ac, or above 3000 V dc. See also **Switch** or **Disconnect**.

Circular Mil (CM): A unit of area defined as the area of a circle having a diameter of 1 mil (1 mil = 0.001 in.). Since this circle has a radius of ½ mil, by using the area formula for a circle

$$\text{area} = \pi r^2$$

the circle encloses an area of $\pi/4$ mil^2 and therefore the following approximations can be made:

$$1\text{CM} = 0.7854\,\text{mil}^2$$

$$1000\ \text{CM} = 1\ \text{kCM} = 785.4\ \text{mil}^2 = .000785\ \text{in.}^2 = 0.51\text{mm}^2$$

Cogen: A facility whose primary purpose is electrical power cogeneration. A cogen is a private corporation that either uses the power it generates or sells part or all of that power to a public utility.

Cogeneration: The process of producing both electrical and thermal energy. Cogeneration plants produce steam and electricity (Combined Heat and Power – CHP).

Color Test: By transmitting light through a sample of an insulating fluid and comparing the color of the sample to a color chart, a color value (from 0.5 to 8) is assigned. A reading above a specified limit or the trend of results is used to evaluate the need for servicing. This test also allows observation of other signs of trouble, such as solids in suspension. It is a common test used in evaluating the condition of transformer oils and can be part of a Gas in Oil Test / Dissolved Gas Analysis (DGA).

Combustible Gas Analysis (With reference to the vapor space in certain transformers): Using a combustible gas detector, a sample of the gas space in a unit having a nitrogen seal or a conservator vent system is analyzed. Total combustible gas readings equal to or greater than 1% suggest the need for additional tests, increasing test frequency and planning corrective action. Readings equal to or greater than 5% suggest the need for immediate internal inspection. This is a common test used in evaluating the condition of transformer oils.

Common Mode Disturbances: Electrical power or signaling disturbances between primary lines and ground. One means of reducing common mode noise in signal circuits is to shield the circuit leads.

Commutation: The switching performed at the commutator and needed for dc machines, reversing current direction as rotation moves a coil through a field. Many factors affect the quality of

commutation, including brush composition and grade, brush pressure against the commutator, brush position and freedom (maximizing contact surface with imperfect commutators), brush location (for proper switching), current density in brushes (brush size and amperage), excessively high or low commutator temperature, breakdown strength of a commutator insulation system, contamination and smoothness of rubbing surfaces, rotor balance and vibration, winding faults, and broken coils.

Sparking, which can burn the edges of bars and brushes, is a sign of poor commutation. Sparking cannot always be eliminated, but should be kept to a minimum. Chipped or cracked brushes, brush chatter, hard glazed commutator surface, flashover, and poor commutator bar coloring are other signs of poor commutation and should be corrected.

Commutator: An assembly of wedge-shaped copper bars arranged so the outer surface forms a rotating cylinder that stationary brushes contact. These bars are insulated from each other and from retaining rings and other supports, usually by strips of mica. Between bars, mica is cut below the commutating surface forming a groove, preventing brush contact with mica. Each bar is part of a motor winding circuit that includes selected coils within the rotor slots. The commutator thus switches circuit connections as brush contact changes from bar to bar in the rotating assembly.

Conductance: The real part of admittance measured in mhos. (See **Admittance**.) The conductance (G) of a conductor is the reciprocal of the resistance (R) measured in ohms. A conductor having a conductance of 1 mho with a dc potential of 1 V end-to-end results in a dc current of 1 A.

Conservator: An expansion tank system for an oil-insulated transformer. Basically, a conservator is an auxiliary tank system designed to be partly filled with oil when the main oil tank is full and when oil temperature and pressure meet design criteria. The conservator and the main transformer tank form a tight system that is sealed from the outside atmosphere to inhibit oil degradation.

Contact Resistance Test: A dc, low resistance test using a microohmmeter with a high current output (like 50 or 100 A, but not more than the rated current of the switching device to be tested) to measure the contact resistance $(\mu\Omega)$ or voltage drop (mV) across closed contacts of a switch.

The test can identify the suitability of the contacts for safe, continued use. Normal wear, erosion, contamination and misalignment cause an increase in electrical resistance across closed contacts, which, by Ohm's law, increases the voltage across these contacts.

Individuals responsible for switchgear maintenance can evaluate the condition of contacts by performing a contact resistance test, reviewing the history of test results, and recognizing the manufacturer's stated service-time and use limitations.

Contactor: A device designed to repeatedly open and close an electrical circuit powering a machine. Contrasted with circuit breakers, contactors switch relatively low non-fault currents, sometimes performing over 200,000 switching operations before requiring replacement. In motor control circuits, switching is frequently accomplished by push-button starting and stopping, but it can also be accomplished by automatic relays.

Coordination Analysis: An analysis of the characteristics and arrangement of protective devices in a circuit. The purpose of electrical coordination is to selectively clear (isolate) faults, overvoltages, and overcurrents in an electrical circuit. Effective coordination minimizes property damage and eliminates or reduces the extent of power outages.

A coordination analysis documents the ratings and capabilities of switchgear (primarily fuses and circuit breakers), including the settings of relays to selectively coordinate their operation. The analysis also correlates insulating strengths of electrical equipment, such as motors and transformers, with expected overvoltages. Thus, the coordination analysis somewhat overlaps with a fault current analysis. In fact, both analyses are commonly completed simultaneously. Deficiencies in selective coordination may be accepted in the design of the system based on economics and informed judgment. However, deficiencies in fault current capacities cannot be tolerated and must be corrected immediately to prevent catastrophic failures. See PRC.5.0.4.

Core: Laminations of magnetic steel sheets, each insulated by a varnish coating, assembled to direct a magnetic field through a path that includes the windings. The sheets are often clamped together

using bolts. Insulation at the bolts and holes prevents electrical connections between laminations through the bolts.

Corona: A luminous discharge resulting from the ionization of air that was electrically stressed beyond its ionization point. Corona commonly appears as a steady, pale violet glow around a pointed or sharp-edged metallic component in a high-voltage electric circuit. Corona can also form in small spaces between conductors at significantly different electrical potentials. Corona causes power losses in circuits. When corona contacts solid materials, it can erode them. Electrical insulation is particularly susceptible. Corona causes radio, television, and audible noise. In an oil analysis, corona refers to overheating of the insulating oil resulting in specific indicators (high hydrogen). If the electrical stress causing corona is increased, the ionization rate increases and flashover can occur. Corona is **not** fire.

Counterpoise: A conductor or a system of interconnected conductors arranged to run below an electric power transmission line, and connected to the footing of each tower or pole supporting that line. The counterpoise assists grounding, particularly for lightning strikes, and can be located above, on, or below the surface of the earth.

Crest Factor: The numerical ratio of a waveform's peak value to its rms value. The crest factor of a sinusoidal waveform is 1.414. The crest factor of harmonically distorted waveforms can be higher or lower; the greater the harmonic content of a waveform, the further from 1.414 the crest factor will be. The accuracy of rms voltage and current measurements is increased by using instruments with higher crest factor specifications. Also see **True-rms Meter**.

Crest Voltage: See **Peak Voltage**.

Current Transformer (CT): An instrument transformer whose primary function is the metering or measuring of current. In a window-type CT, the secondary winding forms the entire doughnut-shaped unit. A line conductor passing through the window is not truly a part of the unit, but it performs the function of the primary winding. For other CT types, the primary can be a conducting segment, like a bus bar or a single-turn conductor, connected in series with the conductor carrying the current being measured.

The turns ratio of a CT is the ratio of the number of secondary winding turns, to the number of turns of the primary windings. The current in the secondary of a CT is regulated to 5 amperes (the standard rating of a CT secondary) by selection of an appropriate turns ratio. The secondary is connected to protective devices, instruments, meters, or control devices. The accuracy of a CT is determined by unique construction features and tests.

Cutout Box: A surface-mounted enclosure with swinging doors to allow access to interior electrical wiring and devices.

Dead Tank Switchgear Device: A switchgear device whose interrupters and dielectric are contained inside a grounded tank.

Derating: Reducing the current and power rating of a device or conductor to compensate for operating conditions outside the normal operating range. As examples, high altitudes, harmonic currents and hot environments are common reasons to derate a transformer. Gas-insulated circuit breakers must be derated when used in extremely cold environments.

Dielectric: Electrical insulation. A dielectric can be a liquid, gas, solid, or vacuum. A perfect dielectric placed between conductors at different electrical potentials permits only capacitive charging current to pass between the conductors. Only a vacuum under a low electrical stress comes close to meeting this ideal condition. Under actual conditions, some small amount of in-phase current passes through the dielectric.

Dielectric Absorption Test: One of the Insulation Resistance Tests. This test measures the insulation resistance under a constant voltage at two fixed times after the voltage is applied, such as at 30 s and at 60 s. Insulation in good condition will develop higher resistance with time. The 60 s/30 s ratio is called the dielectric absorption ratio. Also see **Polarization Index Test**.

Dielectric Strength (or **Breakdown) Test**: A dielectric test that increases voltage at a specified rate to find the highest withstand point (kV) before electrical failure or breakdown of the insulating liquid occurs. A low test result suggests poor oil quality due to contamination from one or more of the following — solids, moisture, dissolved gases, or acids. Two test methods are commonly used. The ASTM D877 procedure tests the fluid breakdown using two flat disk electrodes. The ASTM D1816 procedure uses spherical electrodes and is better able to detect moisture. Pass/fail criteria differ for these two methods. The ASTM D877 procedure is the older of the two, and it is the test most often used in evaluating the condition of transformer oils.

Differential Relay: A quick-acting relay that senses an imbalance in current flow into and out of a protected area. It has the advantage of including in its zone of protection part of the primary and/or secondary bus, including circuit breaker, transformer windings and bushings. When the difference between monitored currents reaches a predetermined setting, the relay operates. Less commonly, differential relays are also made that operate on voltage differences.

Directional Relay: A relay that responds to the phase position of current or voltage.

Disconnect: A switch used for changing connections in a circuit, including disconnecting equipment from a power source. It is required to operate under limited current conditions and also when no significant voltage change occurs at either terminal. An engineering analysis is required to evaluate the safety of performing an equipment disconnect function under load.

Dissipation Factor Test (With reference to testing of insulation): A test yielding the ratio of real power to reactive power (VAR). Also see **Power Factor**.

Dissolved Gas Analysis (DGA): See **Gas-In-Oil Analysis**.

Distance Relay: A relay operated by control equipment that monitors a circuit for faults within a prescribed electrical distance from the monitoring point. The control equipment can monitor admittance, impedance, reactance, or resistance.

Ditertiary Butyl Paracresol (DBPC): An organic additive to transformer oil that inhibits oxidation. It is added after the filtering process, since filtering strips natural inhibitors from the oil.

Duct: An enclosed electrical raceway. A duct carrying a conductor or a group of conductors to feed two or more circuits is a bus duct.

Ductor or Ducter® Test: A low resistance ohmmeter test.

Dummy Fuse: A copper rod sized to replace a specific fuse and fit its fuse holder with the same pressure, contact and cross-sectional area. Dummy fuses are sometimes provided with fused switchgear for testing.

Duty: The operating conditions to which a machine or apparatus is subjected. Continuous duty suggests that the equipment is designed to operate at a substantially constant load for an indefinitely long period of time. Intermittent duty suggests that the equipment is designed to operate at a substantially constant load during specified loading cycles alternating with specified intervals of rest and no-load. Short-time duty suggests that the equipment is designed to operate at a substantially constant load for a specified short period of time.

Eddy Current: A circulating current in a metallic part. This current is induced by changes in a surrounding magnetic field caused by nearby equipment and conductors. In electrical systems, eddy currents can cause energy losses and undesirable component heating. The thin insulated laminations in the cores of transformers are designed to limit eddy currents.

Electrical Metallic Tubing: A raceway conforming to NEC Article 348.

Electro-Magnetic Interference (EMI): An undesirable nonsinusoidal electromagnetic disturbance that can affect how a device or circuit functions. EMI can impair or hide desired signals and if high enough can interfere with adjacent circuits.

Excitation Current Test: An ac test that is an alternative for the TTR test. Its discussion is beyond the scope of this document. Also see **Transformer Turns Ratio (TTR) Test**.

Expert System: An automated operating, process, protective, or management system that includes a computer program to mimic the thought process of a human expert.

Explosionproof Apparatus: Apparatus having a tight enclosure or case that can:

- Withstand internal explosion pressures from gases and vapors.
- Prevent internal explosions and resulting flames and hot particles from spreading to identical gases and vapors outside the case.
- Maintain an external temperature below the ignition temperature of surrounding flammable atmospheres under all operating conditions.

Nationally recognized testing laboratories in the U.S. test explosionproof electrical equipment to the ANSI/UL 1203 standard. The International Electrotechnical Commission (IEC) tests “flameproof” electrical equipment to IEC 79-1. Because the requirements of these two standards are different, the equipment passing them cannot be easily compared. Explosionproof and flameproof equipment should be used for the country and codes for which the equipment was designed.

Faraday Cage: A mesh of electrical conductors that form an enclosure to shield objects within from electrical contamination. Cage size, arrangement, function and construction can vary greatly. Faraday cage examples include screen rooms, all-metal buildings and lightning protection systems formed by lightning rods and large-gauge bare conductors.

Fault: A broadly applied term commonly meaning the occurrence or result of a rupture in electrical insulation (the electrical breakdown of a dielectric resulting in leakage current, sometimes described as insulation breakdown, and the steady-state result.) This electrical breakdown can result in a ground fault, a phase-to-phase fault, or in a fault to a floating or grounded neutral. “Bolted through-faults” and “short circuits” are low electrical resistance faults. High resistance, high impedance faults produce low fault currents. The term “fault” also applies to an electrical failure of a conductor, as when a break causes the loss of electrical continuity.

Fault Current: The current flowing from one conductor to ground or to another conductor due to an abnormal connection between the two, such as during arcing or insulation breakdown.

Fault Current Analysis: The part of the coordination analysis that evaluates the capabilities of switchgear. It looks only at short circuit currents and equipment ratings.

Ferroresonance: A phenomenon associated with overvoltage swings and irregular waveshapes. Ferroresonance is caused by excitation of one or more saturable inductors through a series capacitor.

Fiber Optic Cable: Data transmission cable containing a transparent glass or plastic fiber core to conduct radiant power or light, but not electric current. Cable sizes describe the core/cladding diameters in microns. Three common sizes are 9/125, 62.5/125, and 200/230. Typically used in communication/data/telephone service, small-core (9/125) fiber is a single-mode fiber since it can pass only one ray of light through its small diameter core.

Small-core fiber cables are difficult to install and maintain, but they do not distort signals that travel over the long distances common to the communications industry. Larger optic fibers are called multimode fibers. They are common in industrial use where signals travel shorter distances. Contrasted with small-core cables, these cables are easier to install, are less expensive, can be used with less expensive auxiliary components, and require less maintenance since they can better tolerate contamination and misalignment.

Field Winding: The winding providing the magnetic field for the poles. This is usually the rotor in an ac machine, and the stator in a dc machine.

Filter Press: A mechanical piping and filter system that removes water and solids from fluids. It may be used to recondition transformer oils.

Fire Resistant Construction (as used in the NEC): A construction having a specified fire rating or a minimum fire rating of one hour where not specified.

First Floor (of a building): An occupied building level defined as that level that has 50% or more of the exterior wall surface area at or above finished grade per NEC.

Flameproof Equipment: See **Explosionproof Apparatus**.

Flashover: A disruptive electrical discharge occurring when a short circuit breakdown path through a gas or along the surface of an insulator becomes sufficiently ionized to maintain an electric arc.

Flexible Metal Conduit (FMC): Per NEC Article 348 it is a raceway of circular cross section made of helically wound, formed, interlocked metal strip.

Flexible Metallic Tubing (FMT): Per NEC Article 360 it is a raceway that is circular in cross section, flexible, metallic, and liquidtight without a nonmetallic jacket.

Fuller's Earth: One of the more common materials used to reduce acidity during the process of reclaiming contaminated oil.

Fuse: A protective device that connects an electric power source to a load, forming a protected circuit. It directly links the source to the load by electrical series connection so that all current flows from the source to the load through the fuse. It protects the circuit (device) by melting or fusing open, severing the link and disconnecting the power source when excessive current is encountered. It is a unique switchgear device in that it is manufactured for the function of destroying itself upon predetermined conditions.

The term "fuse" can refer to a single component, or the assembly of components required for the protective device to be connected to the circuit, including the fuseholder. However, when a fuse is one component of a device serving another purpose, e.g., a "fused disconnect," the term refers only to the component(s) serving the limited function of fusing.

Gauge: A system numerically defining the size of a wire or cable. Also see **AWG**.

Gas Accumulator Relay: An on-line relay that collects all or part of the gas formed as an oil dielectric breaks down. The device accumulates the gases as bubbles enter a collecting chamber. A gas accumulator relay can detect gradual breakdown of an oil dielectric before electrical breakdown becomes severe. These relays detect incipient faults involving windings, cores, and poor connections. Also, see **Buchholz Relay**.

Gas-In-Oil Analysis: Also called Dissolved Gas Analysis (DGA) and Gas Chromatography, a test performed on transformer oils to analyze dissolved combustible gases. This test can be done without the need for power shutdown by taking a sample of oil to a lab. Often, the early stages of the development of a failure can be detected, allowing preventive and corrective measures to be taken. Detection of acetylene indicates arcing has taken place in the transformer.

With other combustible gases, the high percentage of a gas suggests the area for review: hydrogen - corona, ethylene - overheating of oil, and carbon monoxide - overheated cellulose insulation. Interpretation of results should be left to the testing organizations involved in such work. This test detects problems more quickly than the Combustible Gas Analysis because gas forms and dissolves in the oil first, reaching the headspace only after the oil becomes saturated.

General-Use Switch: A switch for use in typical distribution and branch circuits that is capable of interrupting rated current at rated voltage (normal on/off switching), but is not capable of interrupting fault or short circuit currents.

Ground Resistance Test: The testing of resistance to ground, preferably measured by the 3 terminal test method.

Guarded Test Circuit: A circuit that is not connected to ground potential during electrical tests. Test instruments often contain terminals for ground connections and for guard connections.

Harmonic Principle: A statement of the physical relationship that says, "Any distorted repeating waveform is the sum of a fundamental waveform plus higher harmonics with frequencies that are exact integer multiples of the fundamental frequency." A corollary to this principle is "Symmetrical

waveforms have positive segments identical to opposing negative segments except for polarity, and have no even harmonic components."

Hazardous Atmospheres: Contaminated atmospheres capable of exposing occupants to death, incapacitation, impairment of ability to self-rescue, injury, or acute illness; including atmospheres with unusually high or low oxygen levels. The term is not adequately descriptive for atmospheres in hazardous (classified) locations. Such atmospheres are defined by the area classification, such as a Class I Division 1 area. A hazardous (classified) location can, but does not necessarily, contain a hazardous atmosphere.

Hazardous (Classified) Locations: Locations in which flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings are expected to create a potential for fire or explosion. The U.S. classification system described in NEC Article 500 lists and defines electrical equipment and circuits required for specific locations. This equipment includes explosionproof, intrinsically safe, purged and pressurized, dust-ignitionproof, dusttight, and nonincendive equipment. National Fire Protection Association (NFPA) Codes and Underwriters Laboratories (UL) standards provide further information.

The International Electrotechnical Commission (IEC) hazardous location approach differs from that used in the U.S. The types of IEC electrical equipment and circuits and methods of protection for equipment used in hazardous areas include flameproof, intrinsically safe, purged and pressurized, increased safety, encapsulation, and sand-filled. Although the IEC and U.S. approaches appear similar, equipment is constructed to different standards and is intended for use in countries using their respective standards.

High Tension Lines: High voltage electric power lines. The term usually refers to utility transmission system conductors. In this context, the word tension usually means voltage. Scientifically, however, tension is the force produced by a longitudinal pull on a cable. This force increases as ambient temperatures cool and an aerial cable contracts; as rain and snow coat a cable and its weight per unit length increases; and as certain forces, including EMF and wind force, pull on a cable. If during system design, cable size or the proposed span between supporting poles must be increased, then cable tension will be higher. Electrically, use of the term "high tension" does not refer to a large force, but rather, an arbitrary high voltage, often in the range of tens of thousands of volts.

High Voltage: An arbitrary voltage range defined by the NEC as "more than 600 V nominal ac voltage." However, other sources define a high voltage electric power system as "having a maximum rms ac voltage above 70,500 V to 242,000 V" and further define two lower ranges as low and medium voltage. The definition depends on the standard and equipment being discussed.

HVdc Transmission Facility: A "high voltage, direct current (HVdc)" electric utility substation that contains converters, bus, and cables for transmitting electrical energy between ac systems. The facility can be part of a long-distance transmission system or can provide a tie between independent, unsynchronized, neighboring, ac systems. The converter can be a rectifier, which supplies dc to the system or tie; an inverter, which changes dc back to ac for distribution or use; or a dual-function unit that can be changed to either a rectifier mode or an inverter mode, depending on the utility system's supply and demand conditions.

Impedance: A vector quantity designating the relationship between voltage and current in an ac circuit. It is a ratio of phasor values and is equal to the steady-state sine wave driving voltage (E) divided by the resultant steady-state sine wave current (I). Impedance (Z) is commonly shown by the formula:

$$Z = \frac{E}{I}$$

Impedance also represents the vector sum of the resistance and reactance of the system, and is expressed as a complex number:

$$Z = R + jX$$

where Z is the impedance, R is the resistance or real part of the impedance, and X is the inductive or capacitive reactance (the "imaginary" part of the impedance.) The X component causes the current to lead or lag the impressed voltage. Z, R and X are all measured in ohms.

Vector sums are often shown in phasor diagrams.

Incipient Fault: The initial stages of a fault condition primarily identified by deterioration of insulation such that electrical breakdown can be predicted to be imminent. Testing and inspection can detect incipient faults.

Instrument Transformer (IT): A special class of transformer that replicates current or voltage in known proportions and phase relationships in its secondary circuit for use in metering, measuring or electrical control circuits. (See **Current Transformer** and **Potential Transformer**.)

Insulation Resistance (IR) Tests: Any of the various dc tests used to measure and compare the conductor-to-conductor, and conductor-to-ground resistances. The principle of these tests is that once a dc potential is applied to an insulator, primarily three types of current losses occur; two are normally decreasing with time and one is essentially constant. Test results are measured in megohms and both the value and trend are analyzed. These tests are nondestructive when properly done. Test voltages, times, and procedures may differ slightly among different maintenance departments.

Insulation resistance tests include Spot-Reading Test, Dielectric Absorption Test, Polarization Index Test, and Step Voltage Test. Refer to each of these entries for further comments. Historically, these tests have been shown to be more meaningful on equipment with solid insulation than on equipment using fluids.

Interfacial Tension Test: A test to measure the strength of an oil-to-water interface. Low readings suggest poor quality oil possibly due to oil deterioration and sludge development. This is a common test used in the evaluation of the condition of transformer oils.

Intermediate Metal Conduit (IMC): Per NEC Article 342 it is a steel threadable raceway of circular cross section designed for the physical protection and routing of conductors and cables and for use as an equipment grounding conductor when installed with its integral or associated coupling and appropriate fittings.

Interrupting Rating: The highest current at rated voltage that an overcurrent protective device is designed to interrupt. This short circuit interrupting rating applies to a single device. When two or more overcurrent protective devices are installed in series to form a single unit, a "series-connected" short circuit interrupting rating may be assigned to the combination of devices. The series-connected rating is established by tests performed on the combination of devices, just as the interrupting rating for a single unit is based on tests.

The main or upstream series-connected device has a unit interrupting rating greater than or equal to the series rating. The rating of a downstream device is less than the series rating.

Intrinsically Safe: Incapable of releasing enough electrical and thermal energy to ignite a hazardous (classified) atmosphere under the worst possible combination of two fault conditions. Intrinsically safe apparatus, wiring, and systems are tested for the hazardous gas or vapor, or combustible dust or fibers in the atmosphere in which the circuit or device is used. Installations in the U.S. comply with NEC Article 504. Equipment is tested to satisfy Underwriters Laboratories ANSI/UL913 requirements. Intrinsically safe equipment is suitable for use in Division 1 locations.

International Electrotechnical Commission (IEC) intrinsically safe installations protect against flammable gases and vapors. IEC equipment meets one of two levels of safety, i_a or i_h. Both types are tested to IEC 79-11 requirements. The i_a type equipment has a higher margin of safety.

Inverter: A device or system that changes dc electrical power to ac power.

Ionization: The process by which electrical stress causes the neutral atoms or molecules of a gaseous dielectric to develop a positive or negative charge. Ionization frees electrons and can cause electrical breakdown. Ionization can produce a corona in air, however, breakdown or arcing can occur before corona forms.

Isolating Switch: A switch intended for maintaining isolation of an electric circuit from a power source once the circuit has already been disconnected. An isolating switch has no interrupting rating and cannot safely open an energized circuit.

Junction Box: An enclosure with a blank cover in which different runs of raceway or cable are joined.

Kick Test: A low voltage dc test whereby the direction of a voltage kick applied to the primary terminals of a transformer is compared to the direction of the voltage response at the secondary terminals to determine additive or subtractive polarity.

Linear Load: A load consisting of resistors, capacitors and inductors such that the current drawn by the load when driven by a sinusoidal voltage will also be sinusoidal and will be at the same frequency as the voltage. Changes in voltage result in proportional changes in current.

Liquidtight Flexible Metal Conduit (LFMC): Per NEC Article 350 it is a raceway of circular cross section having an outer liquidtight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core with associated couplings, connectors, and fittings for the installation of electric conductors.

Liquidtight Flexible Nonmetallic Conduit: Per NEC Article 356 it is a raceway of circular cross section of various types as follows:

- A smooth seamless inner core and cover bonded together and having one or more reinforcement layers between the core and covers, designated as Type LFNC-A
- A smooth inner surface with integral reinforcement within the conduit wall, designated as Type LFNC-B
- A corrugated internal and external surface without integral reinforcement within the conduit wall, designated as LFNC-C

LFNC is flame resistant and with fittings and is approved for the installation of electrical conductors.

Live Tank Switchgear Device: A switchgear device whose interrupters and dielectric are contained inside a tank that is not at ground potential.

Low Resistance Ohmmeter Test: A test to measure very low resistances ($\mu\Omega$ or less) associated with electrical contacts and connections. Contacts in circuit breakers and similar switches, and connections of cable and wiring, splices, electrical bonds and fuses, normally add negligible electrical resistance to a circuit. But as a contact or connection deteriorates, electrical resistance and power losses increase. Corrosion on battery posts, cold flow of metal involving bolted connections on bus ducts, and switch contact wear can result in significant increases in resistance and heat, particularly across joints carrying high currents. (Also see **Contact Resistance Test**.)

Low Voltage: An arbitrary voltage range defined as “not high voltage” when used in the context of NEC. However, other standards define low voltage circuit breakers as those used on circuits rated 1000 V ac and below, and 3000 V dc and below. In contrast, a low voltage fuse is one rated 600 V or less. The meaning of the term low voltage depends on the standard and equipment being discussed.

Metal-Clad Switchgear: Protected Metal-Enclosed Switchgear, conforming to an established standard that requires insulation on all buses, grounded metal barriers completely enclosing all device(s), draw-out main device(s), and other specific protective features.

Metal-clad switchgear is readily serviceable, because major components can be unplugged or “racked out” for tests and servicing. New and repaired components can normally be just as easily “racked in.” Although racking makes preventive maintenance easier, racking sometimes leads to carelessness. For instance, a draw-out circuit breaker might slide out so easily that service personnel mistakenly believe that the unit can be slipped right off its rack without the assistance of a crane or similar supporting machinery. Such reasoning has caused many breakers to be dropped and

damaged. Also, the ease of racking in breakers has mislead service personnel into thinking stabs were properly seated, but when these breakers were energized, loose or misaligned stab connections caused arcing faults.

Metal-Enclosed Switchgear: A switchgear assembly surrounded by a metal case, which may include bare bus, interrupter switches, power fuses, instrument transformers, control wiring and accessory devices.

Mho: A unit of measurement commonly used to express the admittance (including conductance and susceptance) in an electrically conductive material. (See **Admittance**.)

Moisture Content Test (Karl Fischer Reaction Method): A test procedure to determine the amount of water dissolved in oil in "parts per million." The temperature of the oil when the test sample is taken greatly influences the results, as higher temperatures increase the solubility of water in oil. This test is described in ASTM D1533.

Motor Control Center: A floor-mounted assembly of one or more enclosed vertical sections having a horizontal common power bus and principally containing motor control units; each vertical section may include vertical power buses to allow motor control units to be installed one above the other.

Motor Controller: A device that controls the operation of a motor, including starting and stopping it. A motor controller must be able to safely interrupt the stalled-rotor current of a motor. Some motor controllers additionally provide motor overload and short circuit protection. Some disconnect a motor from the power line upon continued overcurrent (over a specified period of time). Some motor controllers are specially designed to allow reversing the direction of rotation of connected motors.

Motor controllers may contain auxiliary devices to limit motor inrush current, torque and speed. Some motor controllers protect against undervoltage, phase reversal and field loss. A simple stop/start switch is not a motor controller.

A magnetic motor starter is a motor controller that combines a contactor with a thermal overload relay. A combination starter is a motor controller that combines a magnetic motor starter with a circuit breaker or fuse in a common enclosure.

Motor Control Unit: A unit assembly including: externally operated circuit disconnect means, branch circuit overcurrent protection, and a magnetic motor controller.

Negative-Sequence Harmonics: The 2^{nd}, 5^{th}, 8^{th}, 11^{th} and higher order harmonics which are all the first order below the triplen.

Network Transformer: A power transformer supplying a circuit whose secondary may backfeed the unit due to interconnection with another supply. Also see **Radial Transformer**.

Neutralization Number Test: See **Acidity Test**.

Nonincendive: Incapable of igniting a hazardous (classified) atmosphere at 1.5 times the energy of the worst possible fault condition. Nonincendive equipment is suitable for use in Division 2 locations.

Nonlinear Load: A semiconductive load like diodes, surge arresters, arcing devices or other switching or distorted-response devices where the current drawn by the load when driven by a sinusoidal voltage is distorted (non-sinusoidal) and does not always change proportionally with voltage. The current changes according to design or control parameters, and not necessarily according to source voltages.

Nonlinear Resistor: A resistor that changes values with applied voltages. Values decrease with increasing voltage and increase with decreasing voltage.

Nonmetallic Wireways: Flame retardant, nonmetallic troughs with removable covers for housing and protecting electrical wires and cables in which conductors are laid in place after the wireway has been installed as a complete system.

Normal Mode Noise or Disturbance: The same as transverse mode disturbance.

One-Line Diagram: A diagram showing, by single lines and graphic symbols, the course of an electric circuit or system of circuits and components.

On-Line Device (for testing, measuring, and diagnosing electrical systems or equipment): A device that functions while the system or equipment being examined operates in its normal energized state. All control instrumentation and many relays are on-line devices.

Overcurrent: Any current in a normal circuit conductive path beyond the ampacity of the involved conductor. Overcurrent can be the excess current because of electrical breakdown of insulation downstream of the conductor, or excess current because of overloading of a downstream machine or circuit. The major causes of overcurrent are overload and short circuits.

Overload: The operation of equipment or devices in excess of normal ratings, which can result in an overcurrent condition somewhere in the circuit. Overload currents differ from short circuit currents in that they remain within normal conducting paths. Overloads can be caused by: too much equipment being run at the same time; too large a load being driven by the shaft of a machine; the improper installation or maintenance of machine shafts and bearings; and excessive duty demands placed on machines, including inadequate intervals of rest or no-load, and blocked ventilation.

Panel: A flat plate-like structure suitable for mounting and wiring electric devices.

Panelboard: One or a group of panels assembled as a single slab, including any mounted devices such as switches, fuses and buses, designed to be placed in a cabinet or cutout box placed in or on a wall and accessible only from the front.

Peak (Crest) Voltage: The highest instantaneous voltage in a power system waveform, excluding small high frequency surge, transient, and oscillatory components. In a sinusoidal ac power system, the peak voltage is 1.414 times the rms voltage. For a typical 120 V (rms) system, the peak voltage is about 170 V.

Phase Converter: An electrical device to convert single-phase power to 3-phase power.

Pickup Voltage or Current (of a relay): The minimum voltage or current required to actuate a relay (operate its contacts) as the signal input increases and when the relay is operating at its design temperature.

Polarity Test (With reference to a transformer): Multiple high voltage windings are usually identified H_1, H_2, H_3, H_4, (and etc. where more than two windings) and low voltage X_1, X_2, X_3, X_4, (and etc.). These may be connected to add polarities (for example, connecting X_2 to X_3) or to parallel windings (connecting X_1 to X_3, and X_2 to X_4). The instantaneous ac current is identical for most of the cycle (the terminals have the same polarity) for all even number terminals. The testing of polarity verifies proper internal connections and may be accomplished by performing a Kick Test or as part of the TTR or Excitation Test.

Polarization Index Test: One of the Insulation Resistance Tests. More specifically, a Dielectric Absorption Test in which the results are expressed as a ratio of the 10 min reading divided by the 1 min reading. A Polarization Index of 2 and above is considered good, however, the trend of indexes is more important.

Positive-Sequence Harmonics: The fundamental, and the 4^{th}, 7^{th}, 10^{th} and higher order harmonics, which are all the next order above a triplen.

Potential Transformer (PT): An instrument transformer whose primary function is the metering or measuring of voltage. Also known as a voltage transformer, and similar in design to conventional power transformers, a PT is shunt-connected to a power supply circuit to measure a voltage between the connection points. The turns ratio of a PT is the ratio of the number of the primary winding turns, to the number of turns of the secondary windings. For most applications, the turns ratio of a PT is selected to set the voltage across the secondary to 120 V when nameplate rated voltage is applied across the primary. PT's are accurate as long as voltage across the primary is within 10% of rated voltage.

Pothead: A device that forms a seal at the end of a cable to provide an insulated egress for the separate conductors.

Power Factor Test: A test yielding the ratio of real power to apparent power. With reference to the testing of insulation, it is the ratio of dielectric loss (watts) to charging VA and approximates the Dissipation Factor; the differences are beyond the scope of this guide.

Preventative Maintenance, Electrical (EPM or PM): A managed program of analyzing and servicing electrical systems to economically maintain production and safe operations. Predictive maintenance, pro-active maintenance, computer-managed maintenance, and other substitute terms have been coined by equipment manufacturers and specialty associations to highlight special PM and test procedures. PM embodies all these philosophies since it includes current and future actions of management, engineering, maintenance and contract personnel to PREVENT AND CONTROL losses through maintenance-related actions. PM typically includes:

- Coordination and fault current analyses.
- Inspections conforming to documented procedures and using written reports, such as check-off lists.
    1. Cursory, comprehensive, break-down, or dismantle inspections.
    2. Visual, auditory, instrument-assisted inspections (thermographic survey, etc.).
- Proof, operational, routine maintenance, and diagnostic tests.
- Scheduled cleaning, lubrication, and overhaul.
- Experience-based adjustments to service schedules. Note: Service schedules are normally based on the type of equipment; its age, use, time in operation, number of operations, environment, and operating conditions; and the degree of reliability needed. Inspections, tests, and instrumentation provide information to support making scheduling adjustments.
- Computer-based maintenance information system activities.
- Performing or contracting for repairs; and other corrective actions.

Programmable Controller or **Programmable Logic Controller**: A special purpose computer that can be programmed to duplicate actions of hardwired electric logic components and relaying schemes. As with any electronic device, a PLC should be maintained in a suitable environment. Heat accelerates aging and reduces the service life of the unit. Programming errors, PLC misapplication, chip deterioration and malfunction as evidenced by random errors, and complete PLC breakdown can initiate or increase a loss. Because of this, hardwired logic systems using relays and other electromechanical control devices are preferred for safety.

Proof Test: An acceptance test for electrical equipment, performed at the point of use and before energizing the unit for service.

Protective Relaying: Combination relay(s) and circuit breaker(s) arranged to disconnect the power to a protected circuit or zone upon reaching predetermined abnormal circuit or ambient conditions capable of causing subsequent damage to the system or components. Protective relays actuate circuit breakers that open circuits when the preset conditions occur. The main types of protective relays are overcurrent, differential, directional and distance relays.

Raceway: A channel for enclosing and loosely holding wires, cables or bus. A raceway may be open or enclosed. It may be constructed of metal or a nonmetallic insulator. Raceways are usually designated by a name closely describing their specific features, rather than by the term raceway, which is generic and broad. Raceways include ducts, rigid metal conduit, rigid nonmetallic conduit, electrical metallic tubing, wireways, cable trays, busways and auxiliary gutters. Raceway installation requirements are described in the NEC. As an example of these requirements, systems extending into areas having widely different temperatures, as from an office area to a cold storage freezer, shall be sealed to prevent circulation of air between these areas.

Radar Test Set: A cable insulation fault detector that delivers one or more high voltage pulses to a cable while continuously monitoring the voltage across the cable's insulation. First, damaged cable to

be tested is disconnected from the power system and all other equipment. Then, the test set is connected to continuously monitor the voltage. A test voltage pulse is applied. All subsequent voltage echoes or reflections are recorded. Trained personnel interpret these results.

Ideally, a voltage is produced across a perfect insulation on a conductor of infinite length only while the pulse is applied. But in reality, voltage echoes occur on less than perfect insulations and shorter cables. These echoes result from changes in the test circuit impedance and can be caused by arcing faults, conductor terminations and splices. If a test set applies a high enough pulse to cause damaged insulation to arc, then the test set will detect an echo from that fault.

Cable radar equipment provides a CRT display (oscillograph) that displays continuous voltage over time. The length of time between a pulse and a returning echo can be used to calculate the approximate distance between the test equipment and the fault.

Radial Transformer: A transformer providing a single feed to a circuit such that the secondary is de-energized when the feed to the primary windings of the transformer is opened. (Also see **Network Transformer**.)

Reactance: The opposition to flow of electrical current from the inductive and capacitive loads of a circuit.

Reactor: An electromagnetic device used to add an inductive reactance component into a circuit by means of one or more windings. This device causes the position of the current vector to shift clockwise, and is used to reduce the overall impedance in a capacitive circuit. A reactor can look like a transformer, but it will have fewer bushings since it does not transform voltage. It requires only half of the connections to a system that a transformer requires.

Rectifier: A device to change ac to dc or to a unidirectional current.

Relay: An electrical or electronic device that responds to a prescribed input signal by causing a switching or contact operation as part of the device's protective, regulating or auxiliary function. Newer, static devices are replacing older, induction cup or disk relays.

Resistance: The opposition to flow of electrical current from the resistive loads of a circuit.

Rigid Metal Conduit (RMC): Per NEC Article 344 it is a threadable raceway of circular cross section designed for the physical protection and routing of conductors and cables and for use as an equipment grounding conductor when installed with its integral or associated coupling and appropriate fittings. RMC is generally made of steel (ferrous) with protective coatings or aluminum (nonferrous). Special use types are red brass and stainless steel.

Rigid Nonmetallic Conduit: A raceway conforming to NEC Article 352, 353 or 354. Similar in definition to above except of non-metal construction. PVC and High Density Polyethylene (HDPE) are the most common types.

rms Voltage: The root-mean-square voltage. The rms voltage of an ac power supply has the same value as the dc voltage needed to dissipate the same amount of heat in a resistive circuit. This is the nominal voltage in an ac system, and is 0.707 times the peak voltage. Unless stated otherwise, ac voltages are rms voltages.

Rotor: The rotating assembly of parts centered within a stator. These can include a shaft, rotor core, windings and insulation system.

Short or Short Circuit: An abnormal current path in an electrical circuit having relatively low impedance and resistance. A short circuit can be accidental or intentional. Arcing can be one form of a short circuit. Also see **Fault**.

Short Circuit Analysis: See **Fault Current Analysis**.

Single-phasing: A condition occurring when one of three leads powering a 3-phase circuit or machine is opened. The voltage of the unconnected (open) terminal responds to the electrical performance of the circuit.

- For a delta-connected load, single-phasing results in supplying the same phase to two of three power connections.
- For a wye-connected load, the power to one phase is lost, but power remains on the other two phases.

Slip: A measure of the loss of speed from synchronous speed.

Slip Ring: Provides continual electrical connection between circuit components that are in motion with respect to one another. Slip rings are used in synchronous and wound-rotor induction motors and in ac generators.

Spot-Reading Test: One of the Insulation Resistance Tests. A selected dc voltage is applied, and 1 min later, the insulation resistance in megohms is recorded. Results are dependent on temperature and volume of an insulation being tested. Results can be corrected for temperature but not for changes in insulation volume or test method. Thus, test equipment and connections should be similar for subsequent tests to allow comparisons. A downward trend in readings suggests that the insulation is deteriorating.

Spring Washer: A conical or split, non-flat, metal washer having a spring characteristic that will allow expansion and contraction of a joint without resulting in the loosening of the joint; used in bolted joints involving aluminum bus; a Belleville Washer is an example of the conical type.

Squirrel-Cage Rotor: A machine rotor with a metal ring or plate at each end, and a succession of shaped, electrically-conductive bars that rigidly connect these ends. Rotor bars can be positioned close together. This assembly forms the rotor's electrical circuit. The name squirrel-cage suggests that the rotor assembly somewhat resembles a cage.

Stabilizing Winding: A delta-connected auxiliary transformer winding, different from the primary and secondary windings, used to stabilize the transformer neutral and minimize system harmonics. Stabilizing windings are not connected to external circuits so the terminals are not brought out of the transformer case.

Stator: The stationary assembly of parts required for generating a magnetic field in rotating machinery. Depending on machine design, these parts can include the frame or shell enclosure, stator core, windings, insulation system, temperature detectors, coolers and supports.

Step Voltage Test: An insulation resistance test that increases dc voltage in equal increments at equally timed steps, and measures the leakage current at a specified time interval after each step. The test continues until the current exceeds expectations, or until the maximum test voltage is reached, whichever comes first. This is called a DC High Potential Test when the top dc voltage step is the equivalent of the 60-Hertz operating crest voltage. Other less demanding IR tests would normally be done first to detect major flaws.

Substation: An group of transformers and switchgear equipment for switching and transforming electric power. Incoming power can be from two or more power supplies, or the substation can separate incoming power into multiple distribution circuits by means of circuit breakers. Service transformer and switchgear equipment, and small distribution transformer installations are not normally considered substations.

Sudden Pressure Relay: A quick acting, on-line relay that detects the rate of rise in pressure of a liquid or gas in an enclosure. The device is commonly used to detect severe electrical breakdown in oil-insulated transformers. Also see **Buchholz Relay**.

Surface Metal Raceway: Per NEC Article 386 it is a metallic raceway that is intended to be mounted to the surface of a structure, with associated couplings, connectors, boxes, and fittings for the installation of electrical conductors.

Surge Comparison Test: A surge test that additionally allows graphical comparison of test results between identical phase windings. Three leads from the test instrument are connected to the three motor or transformer leads. Upon surging the coils, three output patterns appear on an oscilloscope screen. When these patterns coincide so that only one pattern can be discerned, the windings are

identical. A short in two turns of one winding shifts the screen position of the pattern for that winding, resulting in two discernible patterns. Surge tests can be done up to the test voltage level found safe by the Step Voltage test.

Surge Test: An electrical test that generates turn-to-turn voltage potential in a phase winding by pulsing a high voltage across the winding.

Switch: A device for opening and/or closing one or more electric circuits. A switch is manually operable, unless otherwise stated.

Switchboard: One or a group of panels assembled as a single slab, including any devices such as instruments, switches, fuses and buses, mounted on the front or back or both sides. Switchboards are not placed in cabinets, but are mounted on open frames accessible from both the front and rear.

Switchgear: Any electrical power switching or interrupting device provided for control, protection, or metering; including associated enclosures and supports. Fuses, circuit breakers and associated components are common forms of switchgear. Also refer to **Metal-Enclosed Switchgear** and **Metal-Clad Switchgear**.

Switch Mode: A power supply regulating technique using high frequency pulses of voltage and current to transfer electrical energy. Modulating the width of these pulses controls the power. Switch mode power supplies are distinct from more common sinusoidal and dc power supplies. Uses of switch mode power supplies are continually growing. Switch mode power is a common source of system harmonics.

Synchronized (Also, Synchronous and Synchronism): The condition, mode, or state of connected ac power systems operating at the same frequency and in which the phase angle displacement between voltages is within predetermined limits.

Synchronous Condenser: A special type of synchronous “motor” that operates only to correct system power factor and is not designed for driving a mechanical load.

Synchronous Speed: The steady state speed at which the magnetic field of a motor rotates. The synchronous speed of a motor depends on the number of poles for which the stator is wound and the frequency of the ac power supply, according to the equation:

$$S = \frac{120\,f}{P}$$

where

S = synchronous speed in revolutions per minute (rpm)

f = frequency of the ac supply in Hz

P = number of poles per phase

A synchronous motor accelerates to and stabilizes at a constant, synchronous speed. An induction motor rotates at less than synchronous speed according to its slip, which varies directly with the motor load.

Tertiary Winding: A transformer winding, different from the primary and secondary windings, that is connected to a load, such as a synchronous condenser, a reactor, or an auxiliary circuit.

Test Link: A dummy fuse.

Thermographic Survey: An examination using an infrared scanning device. See PRC.1.3.1.

Thumper: A cable fault-finding test set that generates periodic high-voltage, audibly arcing surges (pulses) across insulation breaks (faults). This test can damage good cable. A thumper is used only on cable known to have damaged insulation. Test personnel walk along the cable route listening for the thump or snap that occurs from arc switching during each pulse. If they cannot easily hear the arcing, the test can take a long time. Special equipment may be needed to amplify the sound.

Transformer and/or Switchgear Room: An interior building enclosure designed to house only electrical equipment of minor fire hazard. Walls, ceiling, floor, and doors should be constructed or surfaced with noncombustible heat resistant material.

Transformer Turns Ratio (TTR) Test: A low voltage ac test that measures the ratio of number of turns in the primary winding to the number of turns in the secondary winding, through use of a reference transformer in the test set. When the transformer under test has tap changers, the test should be performed at each tap position. This test also checks polarity. The TTR should be within 0.5% of the nameplate ratio, and should never change.

Transformer Vault: A room having: walls, roof, and floor of 3-h fire resistance rating (6 in. or 152 mm thick reinforced concrete); doors leading to connected buildings of 3-h rating (1-h where fixed protection is provided); a 4 in. (102 mm) or higher sill or curb (to hold volume plus 10% of largest spill possible from a single unit); limited access with locks on doors; outside ventilation sufficient to prevent excessive temperature rise on the transformer; and no storage of materials and no foreign pipe or duct systems allowed therein. Floor pitch and drainage may be required. Vent opening size and covering may be dictated. Minimum wall thickness may be reduced to 4 in. (102 mm) under certain conditions.

Refer to NEC Article 450, part C, for specific details. The construction must also follow local codes. In some cases, additional features may be required, e.g., see NEC Article 502.100 A.

Transverse Mode Disturbances: Electric power or signaling disturbances occurring line-to-line or between two conductors. A common means of reducing transverse mode noise in electrical signal circuits is to twist associated pairs of signal wires for the lengths of their runs.

Triplen Harmonics: The third, and all integer multiples of the third harmonic. Also called zero-sequence harmonics.

True-rms (or **"T-rms") Meter**: An instrument for accurately measuring the rms value of a voltage or current waveform. These meters contrast with "averaging" type meters, which measure the average value of the positive portion of a waveform, and instantaneous or peak-reading meters. While averaging and instantaneous meters are frequently scaled to show an rms value, the scaled value corresponds to a sinusoidal waveform. Meters that are not true-rms meters are inherently inaccurate for nonsinusoidal waveforms, and they generally register voltages less than the actual voltage.

- A true-rms meter may have a "peak" mode to allow dual measurements.
- A true-rms meter designed with an appropriate "crest factor" and bandwidth specification accurately measures the rms value of a nonsinusoidal waveform. The crest factor specification is proportional to the level of peaking that can be measured without errors. The higher the crest factor specification and bandwidth, the higher the accuracy of the instrument in measuring distorted waveforms. Meters designed for a waveform crest factor of 3.0, and having a bandwidth of 2kHz, will be accurate for most power system measurements.

Type I or **Type II Construction**: Construction in which structural members are of approved noncombustible or limited-combustible materials as described in NFPA 220.

Underfloor Raceway: A raceway suitable for use in and flush with the top surface of a floor, and conforming to NEC Article 354. An underfloor raceway is often a trench with a flat metal top.

Unit Substation: An assembly of transformer(s), switchgear, and associated components, mechanically and electrically connected, often housed in a single enclosure, with electrical components designed to provide effective coordination.

Varnish, Electrical Insulating: A liquid resin and solvent system applied to an electrical component, and the film or coating formed as the system cures. The protective film or coating increases the electrical, mechanical, thermal and chemical resistance of the component.

Water Spray: Fixed-pipe water-based protection systems using directional spray nozzles and following the requirements of NFPA 15.

Wire Size: Wire Gauge. Also see **AWG**.

Wireway: A sheet-metal trough with a hinged or removable cover, forming a raceway that meets the requirements of NEC Article 362.

Zero-Sequence Harmonics: The third harmonic and all integer multiples of the third harmonic. Also called the triplen harmonics.