Surge Arresters

Insulation and Arresters
Terms and Definitions

Proper analysis for surge arrester application studies requires, among other things, a comparison of surge arrester protective characteristics with the various insulation levels of the protected equipment. The following terms and definitions explain these various characteristics so that proper comparisons can be made. Definitions of various design tests to assure arrester durability are also given.

GENERAL TERMS

Flashover—a disruptive discharge *around or over* the surface of an insulator.

Sparkover—a disruptive discharge *between* electrodes of a protective device.

Withstand Voltage—highest value of applied voltage at which equipment will not flashover.

Surge-Wave Description—the wave shape of an impulse (other than rectangular) of a current or voltage is designated by a combination of two numbers. The first, an index of the wave front, is the virtual duration of the wave front in microseconds. The second, an index of the wave tail, is the time in microseconds from virtual zero to the instant at which one-half of the crest value is reached on the wave tail. Examples are 1.2 x 50 and 8 x 20 waves.

The wave shape of a rectangular impulse of current or voltage is designated by two numbers. The first designates the minimum value of current or voltage which is sustained for the time in microseconds designated by the second number. An example is the 75A x 1000 wave.

Virtual Zero Point (of an impulse)—the intersection with the zero axis of a straight line drawn through points on the front of the current wave at 10 percent and 90 percent crest value, or through points on the front of the voltage wave at 30 percent and 90 percent crest value.

Virtual Duration of Wave Front (of an impulse)—the virtual value for the duration of the wave front is as follows:

1. For voltage waves with wave front duration less than 30 microseconds, either full or chopped on the front, crest, or tail, 1.67 times the time for the voltage to increase from 30 to 90 percent of its crest value.
2. For voltage waves with wave front duration of 30 or more microseconds, the time taken by the voltage to increase from actual zero to maximum crest value.
3. For current waves, 1.25 times the time for the current to increase from 10 to 90 percent of crest value.

BIL—a contraction of "Basic Impulse Insulation Level" which is a *reference full wave impulse* withstand level expressed as *crest* voltage of a standard 1.2 x 50-microsecond wave shape.

TYPES OF IMPULSE WITHSTAND VOLTAGE TESTS APPLIED TO INSULATION

Full-Wave Withstand—the industry-accepted standard test-voltage wave shape for all types of insulation is 1.2 x 50 microseconds with a continued gradual decay to zero on the wave tail. The crest value is frequently referred to as BIL.

Chopped-Wave Withstand—an applied test voltage which begins as a basic 1.2 x 50-microsecond wave but is "chopped" (caused to decay to zero very rapidly) by the sparkover of a suitable shunting air gap at or shortly after crest. Both power and distribution transformer standards specify chopped-wave and full-wave withstand levels. Values run approximately 115 percent of full wave.

Front-of-Wave Withstand—an applied test voltage with a specified (and relatively steep) rate of rise of voltage which is "chopped" at a specified time *before* the normal wave crest is reached—usually one-half microsecond. Power Transformer Standards specify a front-of-wave withstand level in addition to the two previously mentioned.

TERMINOLOGY OF ARRESTER CHARACTERISTICS

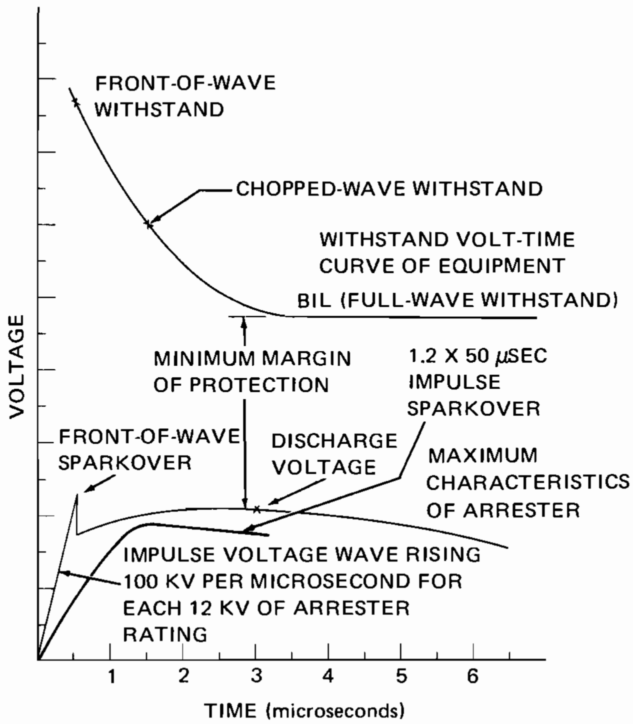
Withstand Voltages of Arrester Insulation—*Power-frequency* withstand voltage and *impulse* withstand voltage of an arrester's insulation are respectively the highest *rms* value of the 60-hertz voltage and the highest *crest* value of the surge voltage that can be applied to an assembled arrester without causing flashover. Since arrester insulation withstand levels must naturally be higher than the arrester sparkover, insulation withstand voltages are determined with *internal conducting parts removed,* or otherwise made inoperative. Any *external series gap electrodes* which shunt an insulating member are removed also.

Arrester Voltage Rating—rms value of the maximum 60-hertz voltage (line to ground) to which an arrester should be subjected even under transient conditions.

Power-Frequency Sparkover—rms value of the minimum 60-hertz voltage that will cause sparkover of an arrester when applied between its line and ground terminals. This sparkover level should be high enough to *prevent* arrester operation on harmless low transient voltages. Presently accepted industry standards state that power-frequency sparkover of an arrester should be at least 1.5 times rated voltage, except for station arresters rated 60 kv and above where the minimum is 1.35 times rating.

1.2 x 50 Impulse Sparkover—the highest standard lightning impulse voltage greater than three microseconds duration which the arrester will allow without sparkover. This arrester sparkover characteristic coordinates with equipment BIL.

Slow-Front *(Switching Surge)* **Sparkover**—the highest crest of voltage with a time duration greater than 30 microseconds and is a measure of the arrester response to switching surges. This characteristic is specified only for arresters rated 60 kv or higher, because it is not normally of concern at lower ratings.



Typical volt-time curve showing arrester characteristics compared with equipment insulation withstand characteristics.

Front-of-Wave Sparkover—the voltage on the front of an impulse wave, rising at a rate of 100 kv per microsecond for each 12 kv of arrester rating, at which the arrester sparks over. The crest value at sparkover should be low enough to prevent the surge from approaching the *chopped wave* withstand of the protected distribution equipment. Some classes of power equipment also specify a front-of-wave withstand level. In such cases, front-of-wave arrester sparkover should be compared to the front-of-wave withstand of the equipment.

Discharge Voltage—the voltage that appears across an arrester conducting surge current. It is expressed in terms of *crest* value of voltage that occurs during flow of surge current of a specified wave shape. The *standard* current wave shape for establishing discharge voltage levels is 8 x 20 microseconds. The *crest* value of the discharge voltage for a standard 8 x 20-microsecond current wave should be *less than the BIL* of the protected equipment by a suitable margin of protection, not less than 20%.

Margin of Protection—the difference between arrester characteristics and equipment withstand level at any given instant of time. This is a factor of safety when considering equipment protection. The margin of protection accounts for various unknowns such as unusually high magnitudes of lightning current, separations of transformer and equipment, and voltage withstand reduction caused by deterioration of old equipment. The margin can be expressed by the general formula:

Minimum percent margin of protection

$$= 100 \left[\left(\frac{\text{insulation withstand strength}}{\text{arrester protective characteristic}} \right) - 1 \right]$$

Duty Cycle Test—a series of 24 discharges, of an 8 x 20-microsecond current wave of a specified magnitude, by an arrester while connected to a 60-hertz power source at rated voltage. This test indicates the durability of an arrester when subjected to repeated lightning surges under actual operating conditions.

Follow Current—the current which flows through an arrester, caused by the power frequency voltage across it, during and after the passage of surge current, It is generally of less than one-half-cycle duration and is primarily of significance in arrester design work. It is of low enough magnitude in McGraw-Edison valve arresters to make its consideration in application unnecessary.

High-Current, Short-Duration Discharge Withstand Test—a series (usually specified by standards as two) of high-current, short-time discharges through an arrester. A 65,000-ampere (4 to 8) x (10 to 20)-microsecond wave is used for station, intermediate, and distribution arresters. The number of times the arrester will withstand the surges exhibits the ability of the arrester to stand up under physical shock of high magnitude lightning current. It also demonstrates the ability of the valve element to carry high surge currents without flashover.

Low-Current, Long-Duration Discharge Withstand Test—a series (usually specified as 20) of low-current, long-time discharges of an approximately rectangular wave shape through an arrester. A 75-ampere, 1000-microsecond wave is specified by standards for distribution arresters. A transmission line discharge test is specified for station and intermediate arresters. The square wave energy in this test is designed to duplicate, on a prorated arrester rating, actual system requirements. The low-current, long-duration test demonstrates the thermal stability of the arrester and its ability to handle repeated switching surges.