OVER VOLTAGES DUE TO SWITCHING SURGES

The increase in transmission voltages needed to fulfill the required increase in transmitted powers, switching surges have become the governing factor in the design of insulation for EHV and UHV systems. In the meantime, lightning over voltages come as a secondary factor in these networks. There are two fundamental reasons for this shift in relative importance from lightning to switching surges as higher transmission voltages are called for:

- Overvoltages produced on transmission lines by lightning strokes are only slightly dependent on the power system voltages. As a result, their magnitudes relative to the system peak voltage decrease as the latter is increased.

- External insulation has its lowest breakdown strength under surges whose fronts fall in the range 50-500 micro sec., which is typical for switching surges.

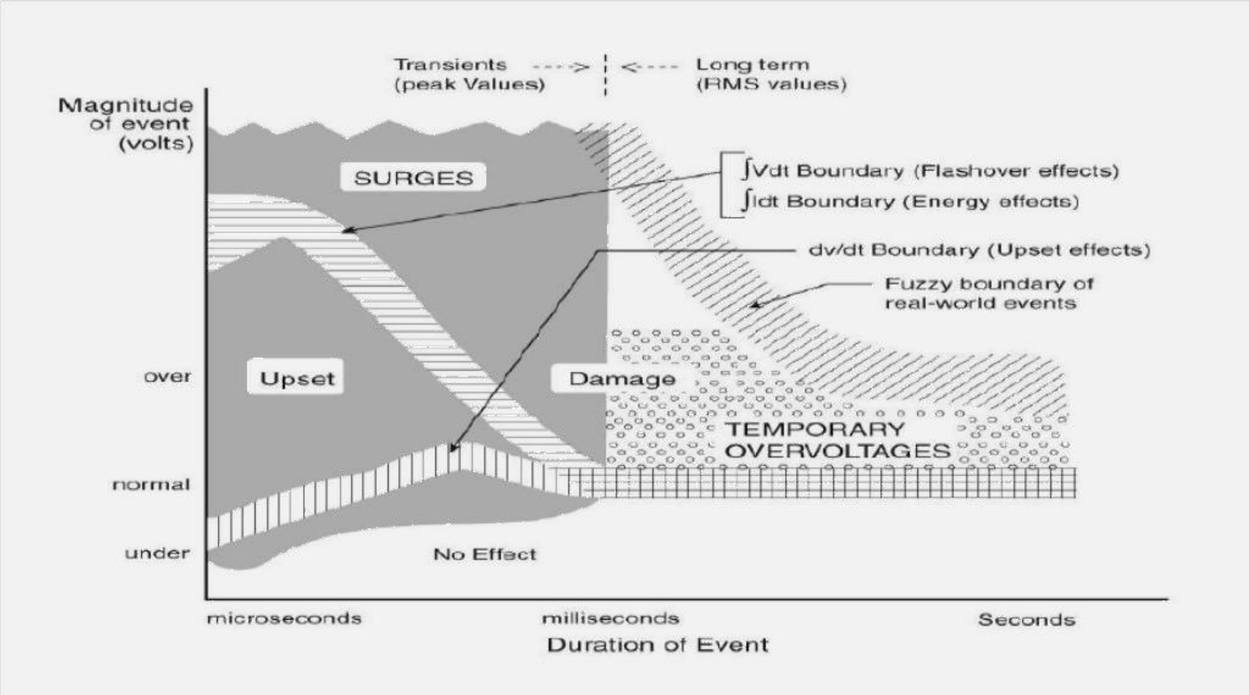
- According to the International Electro-technical Commission(IEC) recommendations, all equipment designed for operating voltages above 300 kV should be tested under switching impulses (i.e., laboratory-simulated switching surges).

Temporary over voltages

The purpose of this Guide is to provide information on transient and temporary over voltages and currents in end-user AC power systems. With this information in hand, equipment designers and users can more accurately evaluate their operating environment to determine the need for surge protective devices (SPDs) or other mitigation schemes. The Guide characterizes electrical transmission and distribution systems in which surges occur, based upon certain theoretical considerations as well as on the data that have been recorded in interior locations with particular emphasis on industrial environments. There are no specific mathematical models that simulate all surge environments; the complexities of the real world need to be simplified to produce a manageable set of standard surge tests. To this end, a scheme to classify the surge environment is presented.

operational upset. Surge protective devices acting primarily on the voltage are often applied to divert damaging surges, but the upset can require other remedies.

Figure 1.4.1 Simplified relationship among voltage, duration, rate of change, and



effect on equipment.

[Source: "High Voltage Engineering" by C.L. Wadhwa , Page – 110]

Temporary over voltages represent a threat to equipment as well as to any surge protective devices that may have been provided for the mitigation of surges. The scope of this Guide includes temporary over voltages only as a threat to the survival of SPDs, and therefore includes considerations on the selection of suitable SPDs. No equipment performance requirements are specified in this Guide. What is recommended is a rational, deliberate approach to recognizing the variables that need to be considered simultaneously, using the information presented here to define a set of representative situations.

Answers may not exist that address all of the questions raised by the considerations listed above. In particular, those related to specific equipment sensitivities, both in terms of component failure and especially in terms of processing errors, might not be available to the designer. The goal of the reader may be simply selecting the most appropriate device from among the various surge protective devices available and meet the requirements of the equipment that they must protect. Subsets of the considerations in this section might then apply, and the goal of the reader may then be the testing of various surge protective devices under identical test conditions. The following can guide the reader in identifying parameters, seeking further facts, or quantifying a test plan.

Desired Level of Protection

The desired level of protection can vary greatly depending upon the application. For example, in applications not involving online performance, protection may only be needed to reduce hardware failures by a certain percentage. In other cases, such as data processing or critical medical or manufacturing processes, any interruption or upset of a process might be unacceptable. Hence, the designer should quantify the desired goal with regard to the separate questions of hardware failure and process interruption or upset.

Equipment Sensitivities

Specific equipment sensitivities should be defined in concert with the above-mentioned goals. The sensitivities (immunity) will be different for hardware failure or process upset. Such definitions might include: maximum amplitude and duration of the surge remnant that can be tolerated, wave-form or energy sensitivity, et cetera.

Power Environment

The applicable test waveforms recommended in this Guide should be quantified on the basis of the location categories and exposure levels as explained in the corresponding clauses of the Guide. The magnitude of the rams voltage, including any anticipated variation, should be quantified. Successful application of surge protective devices requires taking into consideration occasional abnormal occurrences. It is essential that an appropriate selection of the SPD limiting voltage is based on actual characteristics of the mains voltage.

Performance of Surge Protective Devices

Evaluation of a surge protective device should verify a long life in the presence of both the surge and electrical system environments described above. At the same time, its remnant and voltage levels should provide a margin below the immunity levels of the equipment in order to achieve the desired protection. It is essential to consider all of these parameters simultaneously. For example, the use of a protective device rated very close to the nominal system voltage might provide attractive remnant figures, but can be unacceptable when a broad range of occasional abnormal deviations in the amplitude of the mains waveform are considered. Lifetime or overall performance of the SPDs should not be sacrificed for the sake of a low remnant.

Test Environment

The surge test environment should be carefully engineered with regard to the preceding considerations and any other parameters that are important to the user. A typical description of the test-environment includes definitions of simultaneous voltages and currents, along with proper demonstrations of short-circuit.

It is important to recognize that the specification of an open-circuit voltage without simultaneous short-circuit current capability is meaningless. Cost Effectiveness The cost of surge protection can be small, compared to overall system cost and benefits in performance. Therefore, added quality and performance in surge protection may be chosen as a conservative engineering approach to compensate for unknown variables in the other parameters. This approach can provide excellent performance in the best interests of the user, while not significantly affecting overall system cost.

Definitions

The definitions given here have been developed by several standards-writing organizations and have been harmonized.

Back Flashover (Lightning):

A flashover of insulation resulting from a lightning strike to part of a network or electrical installation that is normally at ground potential. Blind Spot: A limited range within the total domain of application of a device, generally at values less than the maximum rating. Operation of the equipment or the protective device itself might fail in that limited range despite the device's demonstration of satisfactory performance at maximum ratings.

Clamping Voltage:

Deprecated term. See measured limiting voltage.

Combination Surge (Wave): A surge delivered by an instrument which has the inherent capability of applying a 1.2/50 us voltage wave across an open circuit, and delivering an 8/20 us current wave into a short circuit. The exact wave that is delivered is determined by the instantaneous impedance to which the combination surge is applied.

Combined Multi-Port Spd: A surge protective device integrated in a single package as the means of providing surge protection at two or more ports of a piece of equipment connected to different systems (such as a power system and a communications system).

Coordination Of Spds (Cascade): The selection of characteristics for two or more SPDs to be connected across the same conductors of a system but separated by some decoupling impedance such that, given the parameters of the impedance and of the impinging surge, this selection will ensure that the energy deposited in each of the SPDs is commensurate with its rating.

Direct Strike: A strike impacting the structure of interest or the soil (or objects) within a few meters from the structure of interest. Energy Deposition: The time integral of the power dissipated in a clamping-type surge protective device during a current surge of a specified waveform. Failure Mode: The process and consequences of device failure.

Leakage Current: Any current, including capacitive coupled currents, that can be conveyed from accessible parts of a product to ground or to other accessible parts of the product.

Lightning Protection System (LPS): The complete system used to protect a space against the effects of lightning. It consists of both external and internal lightning protection systems.

Lightning Flash To Earth: An electrical discharge of atmospheric origin between cloud and earth consisting of one or more strikes.

Lightning Strike: A single electrical discharge in a lightning flash to earth.

Mains: The AC power source available at the point of use in a facility. It consists of the set of electrical conductors (referred to by terms including service entrance, feeder, or branch circuit) for delivering power to connected loads at the utilization voltage level.

Maximum continuous operating voltage (MCOV): The maximum designated root-mean-square (rms) value of power-frequency voltage that may be applied continuously between the terminals of the arrester.

Measured limiting voltage: The maximum magnitude of voltage that appears across the terminals of the SPD during the application of an impulse of specified wave shape and amplitude.

Nearby strike: A strike occurring in the vicinity of the structure of interest.

Nominal System Voltage: A nominal value assigned to designate a system of a given voltage class.

Nominal Arrestor voltage: The voltage across the arrestor measured at a specified pulsed DC current, IN(dc), of specific duration. IN(dc) is specified by the arrestor manufacturer.

One-Port SPD: An SPD having provisions (terminals, leads, plug) for connection to the AC power circuit but no provisions (terminals, leads, receptacles) for supplying current to the AC power loads.

Open-circuit voltage (OCV) : The voltage available from the test set up (surge generator, coupling circuit, back filter, connecting leads) at the terminals where the SPD under test will be connected.

Point of strike: The point where a lightning strike contacts the earth, a structure, or an LPS.

Pulse life: The number of surges of specified voltage, current amplitudes, and wave shapes that may be applied to a device without causing degradation beyond specified limits. The pulse life applies to a device connected to an AC line of specified characteristics and for pulses sufficiently spaced in time to preclude the effects of cumulative heating.

Response time (arrestor): The time between the point at which the wave exceeds the limiting voltage level and the peak of the voltage overshoot. For the purpose of this definition, limiting voltage is defined with a 8/20 Its current waveform of the same peak Current amplitude as the waveform used for this response time.

Short-Circuit Current (Scc): The current which the test set up (surge generator, coupling circuit, back filter, connecting leads) can deliver at the terminals where the SPD under test will be connected, with the SPD replaced by bonding the two lead terminals. (Also sometimes abbreviated as SCI).

SPD disconnect or: A device for disconnecting an SPD from the system in the event of SPD failure. It is to prevent a persistent fault on the system and to give a visible indication of the SPD failure.

Surge Response Voltage: The voltage profile appearing at the output terminals of a protective device and applied to downstream loads, during and after a specified impinging surge, until normal stable conditions are reached.

Surge Protective device (SPD): A device that is intended to limit transient overvoltages and divert surge currents. It contains at least one nonlinear component—a surge reference equalizer. A surge protective device used for connecting equipment to external systems whereby all conductors connected to the protected load are routed—physically and electrically—through a single enclosure with a shared reference point between the input and output ports of each system.

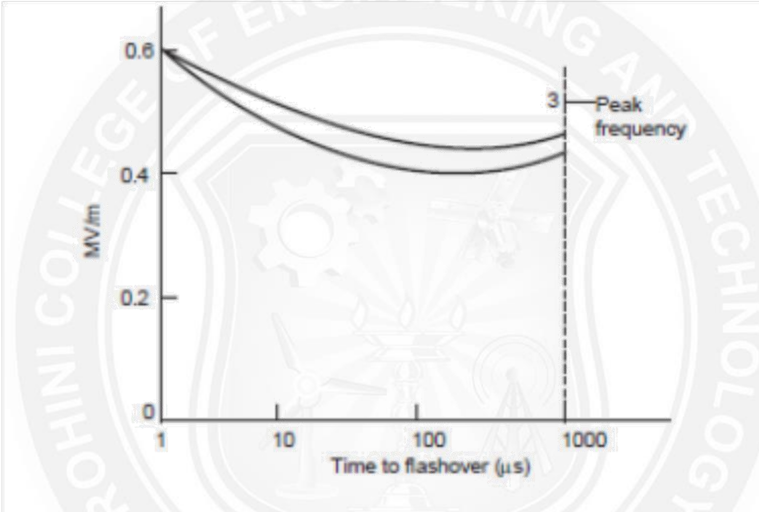


Figure.1.4.2 Variation of F.O. V/m as a function of time to flashover

[Source: "High Voltage Engineering" by C.L. Wadhwa , Page – 121]

It can be seen that the standard impulse voltage (1/50 μ sec) gives highest flashover voltage and switching surge voltage with front time varying between 100 to 500 μ sec has lower flashover voltages compared to power frequency voltage. The flashover voltage not only depends upon the crest time but upon the gap spacing and humidity for the same crest time surges.

It has been observed that the switching surge voltage per meter gap length decreases drastically with increase in gap length and, therefore, for ultra high voltage system, costly design clearances are required. impulse is lower than the negative polarity switching impulse.

It breakdown voltage of positive and gaps increases approximately 1.7% for 1 gm/m3 increase in absolute humidity. For testing purposes the switching surge has been standardized with wave front time 250 µ deceit is known that the shape of the electrode has a decided effect on the flashover voltage of the insulation.

Lot of experimental work has been carried on the switching surge flash over voltage furlong gaps using rod-plane gap and it has been attempted to correlate these voltages with switching surge flash over voltage of other configuration electrodes.

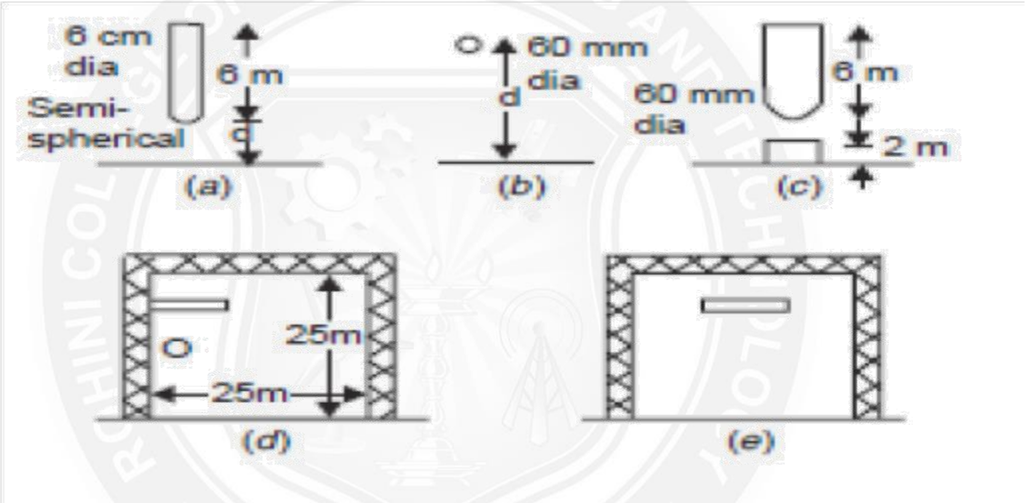


Figure.1.4.3 Different gap geometries

[Source: "High Voltage Engineering" by C.L. Wadhwa , Page – 126]