Data Sheet

Surge protection devices - A technical overview

Introduction

This data sheet covers the following topics:

Types of electrical disturbance.

Sources of surges & RFI.

Problems caused by surges & RFI.

How surges & RFI enter a system.

Magnitude of voltage voltages.

Surge protection components.

Note: Specifications/installation engineers should refer to BS 6651: 1992 - "Code of practice for protection of structures against lightning", so that they are familiar with the details of its guidance and information.

Warning: Attention is drawn to the danger of carrying out maintenance work on lightning protection systems or surge protection devices during a storm.

Types of electrical disturbances

Disturbance	Definition	Where they occur
Spike (commonly referred to as a surge)	Short transient deviation of line voltage from the nominal operating level	Power, data and telecom lines
RFI	Radio frequency interference. High frequency burst of low voltage, low energy spikes	Power data and telecom lines
Overvoltage	Long duration rise in voltage lasting for $^1/_2$s. or more	ac power lines
Surge	Short duration rise in voltage lasting for less than $^1/_2$s.	ac power lines
Undervoltage	Long duration decrease in voltage lasting for $^1/_2$s or more.	ac power lines
Sag	Short duration decrease in voltage lasting for less than $^1/_2$s.	ac power lines
Power cut	Complete loss of power	ac power lines

Note: "Spikes" are often referred to as "surges" or "transients" which, by the above definition, is incorrect. However, this is common and accepted practice and the term "surge" is used to mean "spike" throughout this data sheet.

Voltage surges are momentary increases in the normal working voltage of a system. Often referred to as "spikes", or "transient overvoltages", these surges can appear on power cables and data/telephones cables alike, causing anything from data loss to the total destruction of equipment. They are generally associated with radio frequency interference (RFI).

Sources of surges and RFI

- Lightning
- Power stations and sub-stations during transformer tap switching
- Power station and sub-station faults
- Distribution line faults
- Power-cross faults
- Generators
- Factory equipment
- Photocopiers
- Air conditioners
- Refrigerators
- Electric drills
- Lift drive motors
- Induction from earth bonding tapes
- Switching of fluorescent lights
- Fuses blowing.

Most of these sources incorporate components that switch power on and off in some way and, therefore, create switching surges. These surges exhibit fast rise and fall times and are one of the major causes of problems for computers.

Problems caused by surges and RFI

- Spurious crashing of computer equipment
- Corruption of data being transferred over communication cables
- Failure of power and interface circuits
- High energy surges, on power or communication lines, can cause immediate hardware failure.
- Low energy surges can cause gradual component degradation leading to eventual and unexpected failure of hardware.

How surges and RFI enter a system

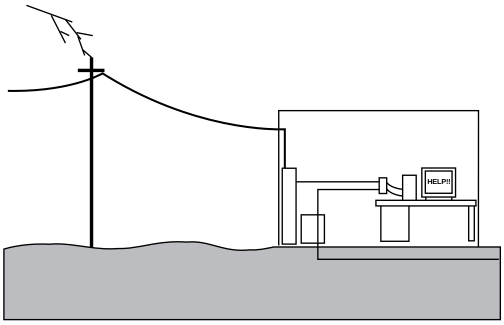
- Conduction via. cabling including power-cross faults (contact between power and communication cables).
- Direct lightning strike to the building structure, radio antennae and external cabling. (Figure 1)
- Induction from nearby surge energy, commonly from localised lightning strikes. (Figures 2, 3 and 4)

The worst voltage surges are usually caused by nearby lightning activity (lightning does not need to hit building or cabling systems to induce massive voltage surges) and can reach up to 6,000V within a building's cabling system, with potential current surges of up to 3,000A.

Direct coupling

- Surge energy present on incoming cables
- Generally caused by lightning strikes, power distribution fault or power-cross
- Direct input of energy to equipment.

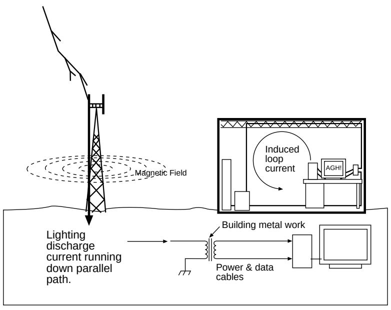
Figure 1 Direct coupling



Inductive coupling

- Electromagnetic field created by flow of current through a conductive path
- Caused by lightning strikes to tall objects, typically trees, and radio antennae
- Surge currents are induced in nearby power and communication cables.

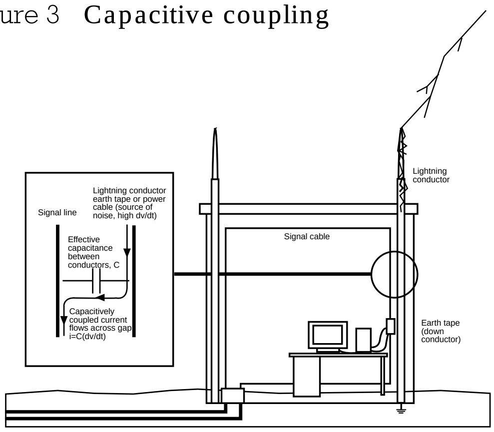
Figure 2 Inductive coupling



Capacitive coupling

- Capacitance between structural protection earth tape and nearby signal (or power) cable allows fast-transient surge energy to flow across gap.
- Caused by direct lightning strikes to building's lightning conductors.
- Some of the surge energy is picked up by cabling.

Figure 3 Capacitive coupling

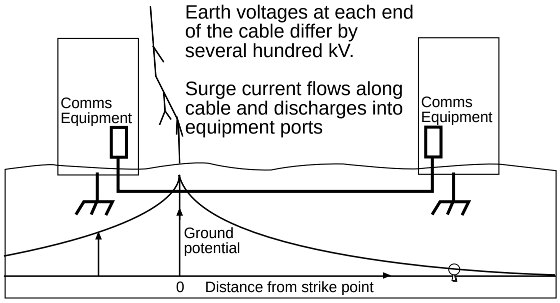


Should a building actually have a lightning conductor scheme to protect its structure, then a lightning strike onto this scheme will generate a large electromagnetic pulse of energy, which will be picked up by nearby cables in the form of a destructive voltage surge.

Resistive coupling (ground potential rise)

- Potential difference between earths of connected buildings
- Caused by nearby lightning strikes
- Communication interface circuits stressed by end-to-end earth difference.

Figure 4 Resistive coupling



The lightning causes a massive raise in ground voltage in the immediate vicinity. This rise is picked up by electrical earthing systems (earthed pipework, etc.) and travels around the buildings electrical system, causing damage to any electronics in its path.

Any data or telecoms cables connecting the affected building to a second building will allow the lightning currents to travel into that building and cause damage there as well.

Magnitude of voltage surges

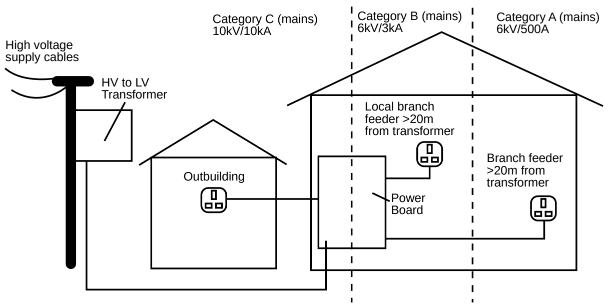
Voltage surges on cabling systems, however caused, will be limited in magnitude by the insulation of the cable itself and any electrical or electronic equipment connected to that cable. In other words, if a rising voltage was applied to a cabling system, a point would come where the insulation of either the cable itself, or equipment connected to it would break down and the voltage would "flash over", thus preventing it rising any further.

IEC 664 defines practical limits for insulation withstand for cabling system within a building. This standard, in conjunction with IEEE C62.41, in which measurements of induced voltage surges on cabling systems are discussed, tells us the maximum voltage surge that is likely to travel along a cable and, hence, the maximum voltage surge that a surge protection device (SPD) will have to divert successfully to protect the equipment connected to the cabling system.

IEEE C62.41 tells us that the largest surge that is likely to appear on the main power distribution board for a building is 6,000V and 3,000Amps. Hence, an SPD device fitted here would have a safely divert this surge to protect equipment connected to that distribution board. The standard goes on to explain that the maximum surge currents caused by lightning are limited by the impedance of the cabling system, which is related to the current rating of the circuit.

A low impedance 1,000Amp busbar distribution board could possibly carry 3,000Amps of lightning induced current, where as, a higher impedance 30amp twin and earth branch circuit, some distance away from the main incoming distribution board, could only pass 200Amps of lightning current, due to its higher impedance.

Figure 5 **High system exposure voltage surge categories for mains power systems (BS6651:1992, appendix C)**



Surge protection devices (SPD) are designed to safely divert these voltages and current surges away from equipment. For the purposes of specifying SPDs, location categories are used which determine the position in which the SPD can be safely used (Figure 5). For mains power systems,categories A,B and C are used, where as, for data/telephone cables, all SPDs should be designed for use in category C. SPDs designed for use in these areas should be tested to protect against the maximum voltage and current surges they are likely to suffer in their category. SPDs not tested to fit into these categories will only provide limited protection and the equipment they are installed to protect may still suffer damage.

Surge protection components

When selecting surge protection components for use in a surge protector, current technology forces the designer to chose between high current handling capability and high speed operation. Surge protection schemes for buildings need to ensure that dangerous surge currents entering a building are reduced to a safe level stage by stage. The let-through voltage of an SPD in each category is an important parameter when designing protection for equipment in the building. Most modern electronic equipment will meet various safety standards such as BS7002, EN60950 or IEC1010 which provide for the equipment to be able to withstand test voltages for electric strength. The test voltage varies according to the type of equipment and the type of test. Earth products meeting BS7002, with a working voltage of less than 250Vrms are tested at 1500V.

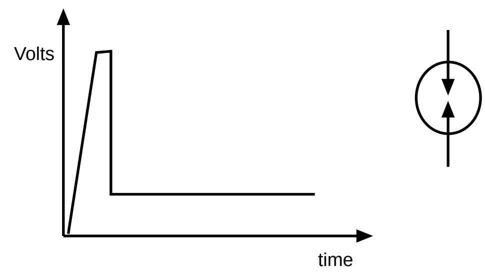
Note: Surge protection devices have a defined life and will not withstand unlimited numbers of surges. Let-through voltages for mains SPDs should ensure that the equipment is not subject to surges in excess of that for which they are designed.

Lightning induced voltage surges can rise from zero to up to 6,000V in around 0.000001 seconds (1 microsecond). Any surge diverting component must operate quickly enough to prevent the voltage surge from passing through. It is for this reason that fuses and circuit breakers do not provide protection. They simply do not work quickly enough.

Components used in modern SPDs are usually selected from three main types:-

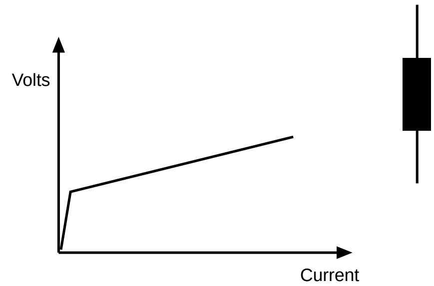
1. Gas discharge tubes, (Figure 6)
2. Metal oxide varistors, (Figure 7)
3. High sped clamping diodes, (Figure 8)

Figure 6 **GDT waveform and circuit symbol**



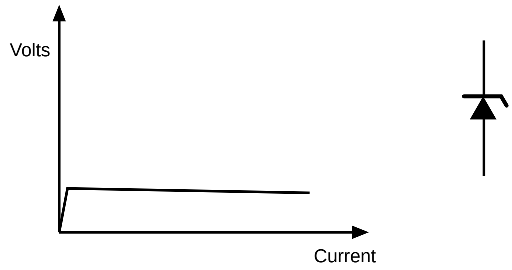
Gas discharge tubes can handle very high surge currents, but are relatively slow to turn on, which means that they let through a lot of surge before they operate.

Figure 7 **MOV waveform and circuit symbol**



Metal oxide varistors can handle a fairly high surge currents, but their clamping voltage rises the more surge current that passes through.

Figure 8 **Zener diode waveform and circuit symbol**



High speed clamping diodes can only handle relatively small surge currents, but they do have very accurate voltage clamping performance.

Applying a building surge protection scheme

Mains

When applying surge protection devices to a mains power system, the ability to withstand voltage surges of the system taken as a whole should be considered, i.e. the surge protection device (SPD) should be matched to limit any surge voltages to a level considered safe for the weakest component in the system. The SPD should also be designed to safely divert the maximum surge current that the system it is installed on is likely to see, i.e. its installation category should be considered, A, B or C (Figure 5).

- Category C level protection
  - first line of defence
  - should be considered first and foremost
  - this protection is installed where cables enter the building and is designed to divert most of the surge energy safely to earth.
  - installed on the incoming power distribution board, modems, CCTV cables etc.
- Category B level protection
  - "second line of defence"
  - removes more of the energy leaving a relatively harmless spike
  - removes surges picked up inside the building
  - installed on power distribution sub-panels
- Category A level protection
  - "last line of defence"
  - used to suppress remaining surge energy and absorb RFI for particularly sensitive equipment
  - installed on the load side of socket outlets, at computer terminals and workstations etc.

Generally, most low voltage power systems (240/415V) and the electronic and electrical equipment designed to connect to them, will safely withstand voltage surges of twice their normal peak operating voltage, i.e. around 700V for 240V systems, (8/20µs waveshape), i.e. 8µs rise time and 20µs fall time.

Specifications for a mains power SPD

Criteria	Performance
Let-through voltage*	<1100V suggested for protecting general office equipment
Modes of operation**	Phase to neutral, phase to earth, neutral to earth
Peak surge current**	Cat B > 20kA Cat A > 5kA
Leakage current	<0.5mA (phase to earth)
Indication	Visual indication of status, including indication of reduced performance
Volt-free contact	This should be provided for high risk applications, where remote indication of reduced protection is required
IP rating	IP## for internal applications IP 65 for outdoor applications
Temperature/ humidity	Suitable for environment
System impairment	The SPD should not interfere with the normal operation of the system into which it is connected. **Note:** Gas discharge tubes should not be connected across mains cables as they can short circuit the supply.

* As tested on the connection terminals of the complete SPD, when tested with the 1.2/50µs voltage and 8/20µs current waveforms appropriate to their location, e.g. 6kV/3kA for Category B.

** The let through voltage should protect equipment on all modes. Sometimes only the phase to earth value is quoted.

*** Peak surge current is an indication of the lifetime of the complete SPD, e.g. a device that will handle a peak surge of 20kA will withstand many lightning induced currents of 3kA.

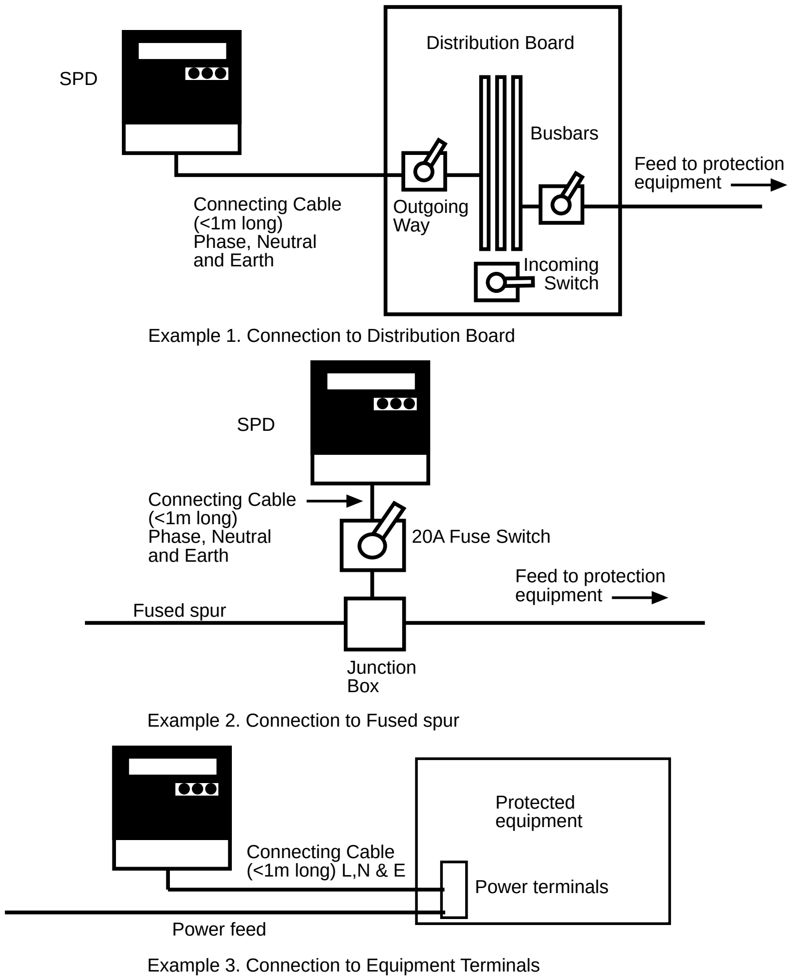
Installing mains power SPDs

There are two types of products. Shunt connecting SPDs are designed for parallel connection to the mains supply, whilst in-line connecting SPDs are designed for series connection between the supply and equipment.

Shunt connecting SPDs

Long connecting leads will impair the effectiveness of the SPD installation, (1m of 16mm^2 earthing cable can have over 300V generated along it's length when a surge of 6kV/3kA is applied to it). Hence, the SPD should be mounted and connected, as close to the electrical system it is to protect, as is possible.

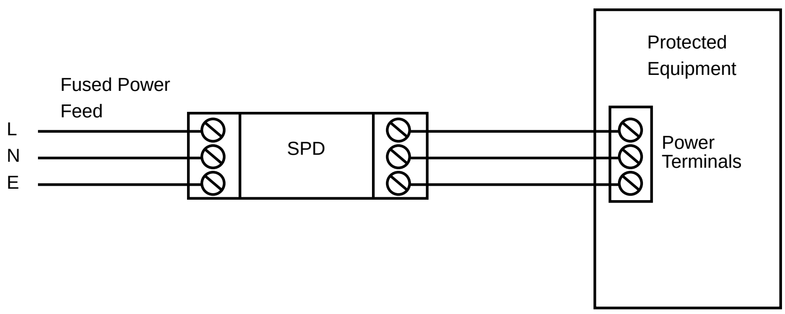
Figure 9 **Typical shunt SPD connection details**



In-line connecting SPDs

Due to the chance of picking up voltage surges in cable runs via inductive and capacitive coupling, in-line connecting SPDs should be connected as close to the equipment to be protected as possible.

Figure 10 **In-line connecting SPD connection details**



Data

When applying surge protection devices to a data/telecomms system, the surge protection device (SPD) should be matched to limit any surge voltages to a level considered safe for the weakest component in the system. The SPD should also be designed to safely divert the maximum surge current that it is likely to see on the system it is installed in. All data cables leaving the building are considered to be in Category C, as the slower surges (10/700µs i.e. 10µs rise time, 700µs fall time) seen on data/telecom cables are not attenuated by cable length to the same extent as a mains power surge is by it's cable.

The steady state voltage on telephone lines is around 50V, but the voltage applied to produce ringing can rise to a maximum of around 145V. Hence, any surge protection device designed to operate on dial-up PSTN lines, should clamp voltage surges at a maximum of around 290V (let through) with a minimum of around 160V (10/700µs), so that it does not interfere with the ringing voltage.

It is important to consider the performance of the complete SPD and claims that devices will react in 10 nanoseconds are misleading because they refer only to the components inside the SPD. The impedance of even the short connections between the terminals of the SPD and its internal components make such a performance impossible.

Specifications for a data/telecomms SPD

Criteria	Performance
Let-through voltage*	Less than twice the peak operating the voltage of the circuit into which the SPD is installed. For dial-up PSTN lines, let through voltage should be between 160V and 290V
Peak surge current**	Cat C high 10kA Cat C low 2.5kA
System impairment***	The SPD should not interfere with the normal operation of the system into which it is installed
Insertion loss	Expressed as an equivalent cable run length
Bandwidth	Normally expressed at the ~ -3dB point in a 50Ω system
In-line resistance	**Note:** If the value for in-line resistance is 0, then there is a good chance that the barrier will not operate at all under some conditions, leaving the system unprotected.
Voltage standing wave ratio	VSWR is an indication of how radio the protector will affect the network
Shunt capacitance	This will affect the bandwidth
Humidity/temperature	The max./min. values should be quoted.

* As tested on the connection terminals of the complete SPD, when tested with the 10/700µs voltage and 8/20µs current waveforms appropriate to their location, e.g. 5kV/125A for Category C., high.

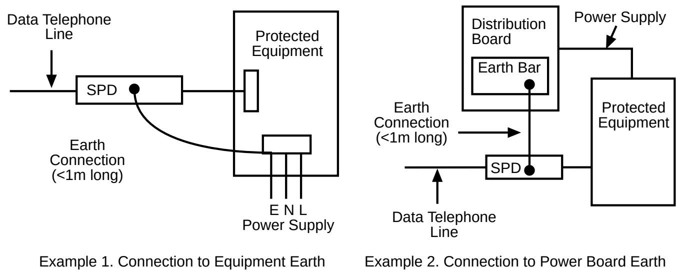
** Peak surge current is an indication of the lifetime of the complete SPD e.g. a device that will handle a peak surge of 10kA will withstand many lightning induced currents of 125A.

*** Oftel, the telecomms watchdog, specifies that equipment connected between the user side of the telecom termination frame and the telephone exchange should comply with Oftel Apparatus Approval Number NS/G/23/L/100005.

Installing data/telecomms SPDs

Generally, all SPDs designed for protecting data and telephone systems connect in-line. The SPD should be located either as close to the equipment it protects, or as close to the main power earth for the protected equipment as possible. The length of the SPD connection to the electrical earth of the equipment should be no longer than 1m in length. Connection of this earth cable can be made to either the earth terminal of the equipment itself, or to the earth bar of the electrical power supply feeding the equipment.

Figure 11 **Connection of data/telecomms SPD earth**



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