Surge Voltage Suppression

The causes of transients, and how to remove them

By Klaus Scheibe

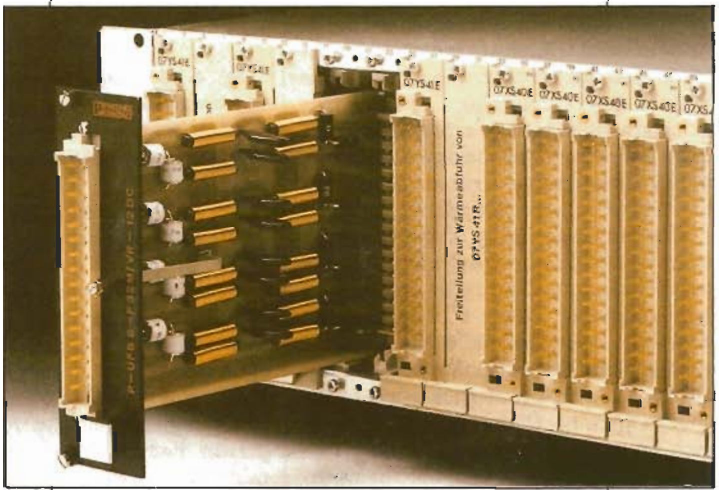
The term "electromagnetic compatibility" is gaining in technical importance. Transient disturbing voltages of varying types can cause failure of electrical and electronic equipment. The intensified interconnections of power supply networks and the growing number of systems generating interfering voltages is causing an increase in the occurrence of transient voltages. In addition, there are more and more sensitive electronic devices for measuring control, regulating and data systems, and so the danger of disturbances and destruction of electronic components grows in proportion.

One of the most significant causes of transient voltages is *atmospheric discharge* (lightning). This can reach current amplitudes of 100 kA and cause short term potential increases at the ground resistors of the affected equipment. The potential increases can reach 100 kV and entail arc-over to other reference potentials.

The lightning current often rises to the peak value within a few micro-seconds. The lightning current wave front duration involved, $S_{1B} = di_B/dt$, is extremely high and reaches values of up to 100 kA/μs. Voltages up to several 100 kV(!) can be induced into a conductor loop located in close proximity to the lightning current carrying conductor.

Switching operations in power supply networks can generate transient compensation on the lines up to the connected low voltage equipment. Here mostly converter measuring circuits are concerned or control conductors monitoring the circuit state or actuating the power switch. Transient compensation can have varying voltage wave front durations. Circuit breakers containing silicon hexafluoride or vacuum are subject to collapse times of the contact break distance within a few ns. In accordance with these short decay times a high frequency interfering voltage develops which is transferred to the low voltage level.

Nuclear explosions may generate *nuclear electromagnetic* pulses (NEMP). The extent of these pulses decisively depends on the altitude and energy of the nuclear explosion; basically it will cover several thousand kilometers. Within a few ns the impulse can reach its peak value, accompanied by electrical field intensities in the kV/m range. The electromagnetic pulses travel through the free space or pass through lines. *Table 1* contains different value referred surge voltages generated by one of the three causes described.



Surge protection is available on Eurocards for rack-mounted computer equipment

Overcoupling the transient voltage from an interfering to an interfered current circuit can be ohmic, inductive or capacitive. The current circuits are directly connected through common impedances. A voltage drop, for example, caused by the short-circuit current at the system ground register, is directly input coupled at the connected low voltage level.

Inductive overcoupling is caused by a non-stationary magnetic field. A lightning conductor for example is surrounded by such a field when lightning is discharged, which induces voltages into nearby current loops.

In the case of capacitive overcoupling by non-stationary electric fields, potential differences and thus electrical field intensities may occur between the interfered and the interfering system. As a result of the time changed potentials the low voltage conductors carry capacitive currents. *Figure 1* represents a schematic of the different types of input coupling.

All types of interferences can lead to damage to or destruction of the electronics in the affected system depending on their amplitude and duration. They endanger the operation of electrical equipment or can lead to failure.

To limit or reduce the level of the generated interference values, direct connections should be reduced or even avoided. Furthermore, plant referenced counter-inductances and coupling capacities between the interfering and interfered system should be kept at a minimum or reduced to the maximum possible extent with the aid of appropriate screening measures.

The installation of protection modules offers a modern and efficient way to suppress or avoid interferences and reduces transient disturbance voltages to non-dangerous values prior to entering electronic systems.

		Atmospheric discharge (lightning)	Switching operation	Nemp
Frequency range	Hz	10^3 to $5 \cdot 10^6$	10^4 to 10^8	10^5 to 10^8
Wage front duration *di/dt*	kA/μs	120	1000	—
Rise time	ns	1000 to 2000 following lightnings 200 to 500	10 to 50	< 10
Electric fields	kV/m	≈ 40 (100 m distances)	≈ 10 (10 m distance)	≈ 50 (1000 m distances)
Magnetic fields	A/m	≈ 160 (100 m distances)	≈ 300 (10 m distance)	≈ 1000 (1000 m distances)

Table 1: Characteristic values of transient interfering factors

THE COMPONENTS

Components suitable to reduce or suppress disturbing voltages are: gas filled surge arrestors, surface discharge arrestors, varistors or diodes or a combination of such components.

Gas filled surge arrestors typically comprise an electrodes arrangement located in a glass bulb or a ceramic tube. The space between the electrodes is filled with low pressure inert gas. Surge voltage lead to a discharge between the electrodes following the ionization process and thus to a well conducting connection. The gas filled surge arrestor ignition depends on the wave front duration of the transient voltage: the steeper the surge voltage the higher the response voltage of the gas filled surge arrestor and the shorter its ignition time. *Figure 2* shows a schematic of the gas filled surge arrestor characteristic. Once the surge arrestor has ignited, its voltage drops to approx. 10 V to 20 V, i.e. the gas filled surge arrestor becomes low resistance. When the surge current has decreased, the power referenced follow current can also be dissipated through the gas filled surge arrestor. The follow current intensity interrupting the surge arrestor depends to a decisive degree on the type of voltage (DC or AC), the voltage level and the circuit design of the power supply circuit. Occasionally encapsulated air spark gaps are used. If there is a dielectric the discharge current is usually higher than that of comparable gas filled surge arrestors. The surge characteristic, as compared with gas filled surge arrestors, is flatter. This means that surge voltages are limited to a nearly constant value of 2 kV and 3 kV independent of the wave front duration.

Varistors are variable resistors. Depending on their concept we distinguish between silicon carbide and metal oxide varistors. The latter version is gaining an

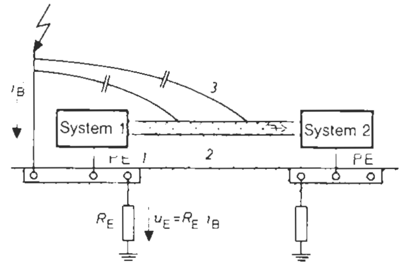


Figure 1: Schematic of input coupling
1 Ohmic
2 Inductive
3 Capacitive

increasingly dominant position due to its favorable UI characteristic. Metal oxide varistors consist of a layer of sintered zinc oxides mixed with other metal oxides. As far as electrics are concerned, this means that the good conducting zinc oxide particles are embedded in a high resistance oxide based intermediate phase and that a multitude of micro-varistors develop at the zinc oxide grain boundaries.

The discharge ability of the varistor is composed of micro-varistors in series and parallel circuits. Zinc oxide is a N-type semi-conductor with a P-type grain boundary layer. In the event of surge voltage peaks the protection components change from high resistance to low resistance in a few ns, absorbing impulse energies. To successfully use metal oxide varistors, note should be taken of their current/voltage characteristic *(Fig. 3)*.

Protection diodes encompass Zener diodes and transient absorption Zener or suppressor diodes. *Zener diodes* are semiconductor components requiring a certain voltage level and featuring a very small differential resistance in the area of the so-called Zener voltage. Being conceptualized for continuous loads, they are also able to reduce lower surge voltages, enabling the discharge of surge currents of up to 200 A. This value is, however, dependent on the protection level of the diode continuous power handling capacity. The response time lies in the lower ns range.

Suppressor diodes are semi-conductor modules, based on the principle of the Zener diode, which distinguish themselves by a very short response time due to

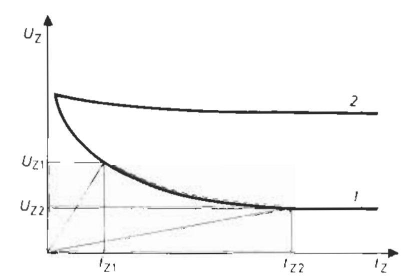


Fig. 2. Schematic illustration of the surge characteristic curve for
1 Gas filled surge arrestor
2 Surface discharge arrestor

their high current carrying capacity. Their discharge capacity reaches several 100 A in spite of a smaller construction design than zeners. Due to a special planar technique, response times of less than 10 ps are reached. The typical UI characteristic of a suppressor diode is shown in *Fig. 4*. The off-state voltage U_R is the highest negative voltage the suppressor diode is able to block. Due to the minimal breakdown voltage U_{BR} a current of 1 mA flows through the suppressor diode. The diode commences limiting the surge voltage. The maximum limiting voltage U_B is the maximum voltage on the suppressor diode in the case of a peak current impulse.

With a combination of gas filled surge arrestor, varistor and diode the advantages of the individual protection elements can be used in a targeted manner permitting protection circuits as per *Fig. 5*.

SURGE BARRIERS

For explanation purposes a two conductor module with artificial ground (*Fig. 5*) has been selected to which as a rule the outgoing and return lines of the measurement, control and regulation (MCR) or data equipment are connected. The gas filled surge arrestor operates as coarse protection, the varistor and suppressor diode combination as fine protection. The potential differences between the individual elements are caused by induction (or through resistances) in the outgoing as well as the return line branches. If the return line is identical to the ground conductor, the coupling elements (chokes or resistances) are not required. The input accommodates solely a surge arrestor between the outgoing and return lines.

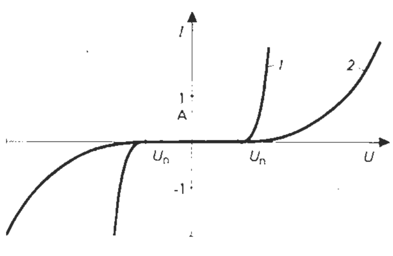


Fig. 3. Schematic illustration of the
1 Zinc oxide varistor
2 Silicon carbide varistor

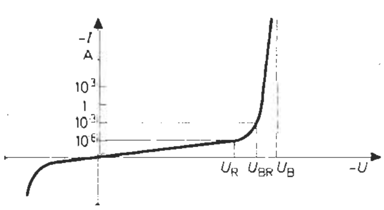


Fig. 4. Schematic illustration of the UI characteristic curve of a suppressor diode

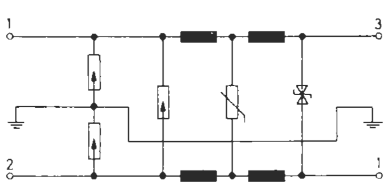


Fig. 5. Circuit diagram of a surge voltage protection module

Fig. 6 shows the attenuation curve dependent on the transmission frequency for the protection module in accordance with *Fig. 5*. The frequency where insertion loss amounts to 3 dB, is termed the cut-off frequency. In the present case it amounts to approx. 1 MHz. Due to the different capacitance levels of the individual protection elements, above all the varistors, the transmission behavior can vary on modules designed for different voltage ratings. For this reason, in *Fig. 6* an attenuation tolerance range is shown dependent on the frequency range.

The protection modules are available for differing voltage types (direct and alternating current) and for different voltage levels. The rated current predominantly depends on the height of the voltage level and the gas filled surge arrestor employed and in general terms lies at around 100 mA to 1000 mA. The gas filled surge arrestor conductance fluctuates within a few ns. In the insulating condition the gas filled surge arrestor resistance is in the gigaohm range and in the conducting condition it can assume a few tenths of an ohm at an arc voltage of about 10 V to 20 V. If the current reduces to values in the mA range, the voltage at the gas filled surge arrestor can increase to the value of the glow potential ranging

between 60 V and 160 V dependent on the individual type. At operating direct voltages smaller than the arc voltage, automatic and secure quenching of the current by the gas filled surge arrestor can be assumed. If, however, glow potential is applied to the gas filled surge arrestor, the current must not increase to an extent enabling it to maintain the charge flow in the gas filled surge arrestor. With alternating current flowing the surge arrestor receives a quenching aid at the natural current zero axis crossings.

Protection modules for limiting surge voltages in MCR and data equipment can generally be obtained up to 220 V and for nominal leakage currents up to 10 kA in accordance with the standardized current form 8/20 (rise time 8 μs, half value decay time 20 μs) *(Fig. 7)*.

Datatrab installs in V.24 data lines using D-submin connectors

The operating current must not, depending on type of voltage and rated voltage, exceed values of several 100 mA to 1 A, in order to always permit automatic extinguishing of the current by the gas filled surge arrestor. If application at higher operating currents is required, one point to bear in mind is the maximum permissible operating current dependent module heating. On the other hand it must be ensured that the low ohm supply network permits a follow-through current through the surge arrestor higher than the operating current and interrupted by a specifically designed fuse.

CONNECTING

When interconnecting fine protection barriers always ensure that the input terminals are directed towards the expected surge voltage. Connect the MCR or data equipment to be protected, to the output terminals. In order to avoid undesired potential increases on the equipment to be protected the housing ground should be taken to the fine protection barrier and there linked to the equipment ground. This excludes unacceptably high voltage levels occurring at the electronic equipment due to current return flow through the ground line. *Fig. 8* shows the installation of a fine protection barrier in an electronic system. The voltage between the outgoing and return line—the normal mode voltage—can be reduced to non-dangerous levels. In the event of a disturbance it normally ranges below twice the peak value of the operating voltage. The voltage between the outgoing and return lines and ground—the common mode voltage—is determined by the response behavior of the gas filled surge arrestor employed and can rise to a value of up to 1,500 V.

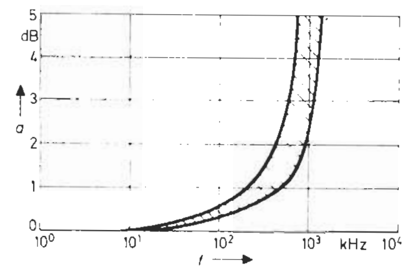


Fig. 6. Attenuation dependent on the transmission frequency of the surge voltage fine protection barrier

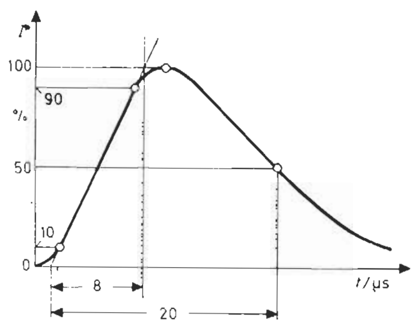


Fig. 7. Surge current 8/20 curve

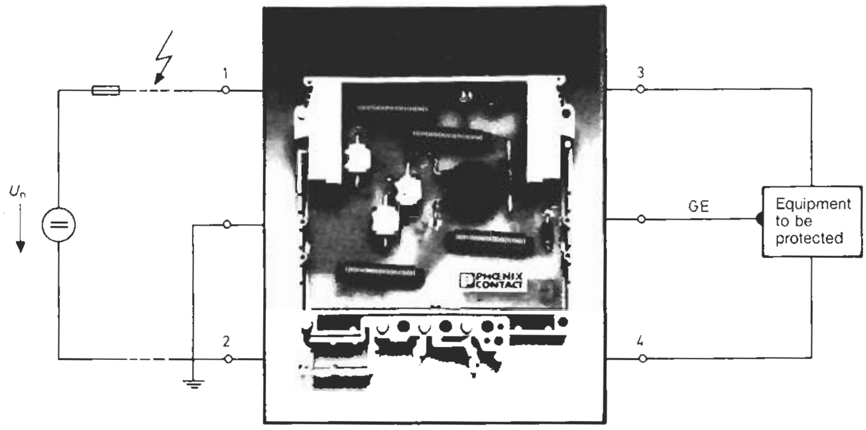
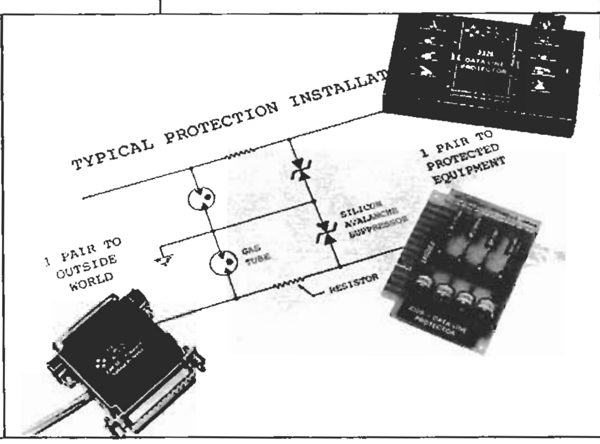


Fig. 8. Interconnection of the surge voltage fine protection barrier to protect sensitive MCR plants from line referenced transient disturbances. GE is group grounding



Phoenix Terminal and General Semiconductor are two suppliers of suppression modules for RS-232 and RS-432 lines

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