APPLICATION OF PROTECTIVE DEVICES TO POWER AND SIGNAL TRANSMISSION LINES

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INTRODUCTION

Experience has established that AC and/or DC powered electrical/electronic equipment is particularly vulnerable to damage from lightning, switching surges and other overvoltage disturbances originating on power distribution facilities. Some types of electromechanical devices are also susceptible to damage from excessive transient voltages from these sources. Overvoltages are also generated within a load complex by switching of equipment, but their magnitudes are generally lower than surges from primary distribution circuits. The application of arresters that are specifically designed for limiting surge voltages on utilization circuits has proven to be an effective means of preventing equipment damage from these common sources of exposure.

Overvoltage surges such as discussed above are inherent in the operation of a power distribution network and cannot be prevented. Providing adequate protection to insure service continuity and minimize maintenance expense must be assumed by the user. AC and/or DC powered equipment is usually designed to withstand "normal" overvoltage conditions such as limited voltage variation and the surges normally experienced when energizing equipment units. This is an economical practice because protection against abnormal overvoltages can be provided for an entire installation by the application of a properly selected and installed power arrester and/or signal protector.

The following sections discuss the electrical and physical properties to be taken into consideration with regard to the nature of the problem (equipment protection), proper selection of an arrester for the defined problem and installation instructions.

ELECTRICAL AND PHYSICAL PROPERTIES TO BE TAKEN INTO CONSIDERATION IN DEFINING A PROBLEM

Does the system have AC, DC, AC on DC, or DC on AC for power or signal circuits? It is not unusual to have a system that has an AC signal circuit; and the same lines are used to carry DC power. These are important factors because the requirements for operating in DC circuits differ greatly from those of AC circuits.

In general, what type of circuit is it; power, signal, combination of both, or other?

What is the minimum insulation resistance that can be tolerated without interfering with the normal circuit operation?

What is the maximum steady-state voltage of the circuit (hot wire to ground) to be protected, or the maximum steady-state line-to-line voltage, in the case of an ungrounded circuit?

What is the maximum voltage that the system might normally see? For example, a 120V RMS AC circuit may often see 135V RMS. If this is the case, the maximum system voltage would be 135V RMS.

What is the minimum voltage the system can withstand that will eliminate any unnecessary interference with the normal functioning of the circuit?

What is the minimum breakdown voltage that will eliminate any unnecessary interference with the normal functioning of the circuit?

How high a voltage can be allowed without damage to the circuit or circuit components in the system? For what duration can this overvoltage condition exist without damage to the circuit or circuit components in the system?

What is the maximum load current of the protected circuitry or circuit components?

What is the total current available when the circuit is shorted at the protective device? (Caution: this has nothing to do with fuse ratings.) If, for example, the power source is the secondary of a power transformer, then the available current is a function of the KVA rating of the transformer. If the power source is a DC power supply, then what is the maximum current that it can supply?

What is system impedance (depends on the system under consideration)? Perhaps wire size and length is all that is available. For example, in communication systems this would typically be 50 or 75 ohms.

What types of transmission lines are used in the system? Are the lines open, twisted pair, coaxial or what? (Approximate lengths are sometimes important.)

What are we attempting to protect from; direct lightning strikes, induced voltage, power cross, switching transients, or other unknown overvoltages?

Economical factors are of utmost importance to the user.

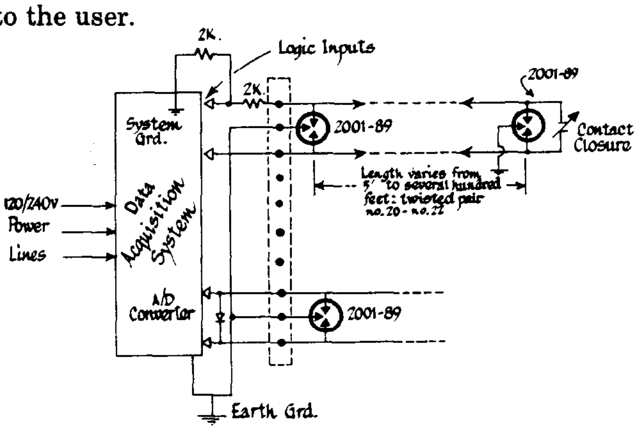

FIG. 1

The above-mentioned properties are common for all applications. However, the use of Digital Acquisition Systems (a typical example in the petroleum industry) discloses the nature of the problem in more detail, and dictates selection of an arrester and its proper installation (see Fig. 1).

Example:

1. A Data Acquisition System to be protected from induced transients
2. AC system 120/240v, single-phase, 60 Hz
3. Both power and signal circuits
4. 3 megohms
5. Power, 120/240v normal condition, 135v RMS maximum
6. Signal circuit, 30v maximum
   a. How high a voltage can the system withstand—1000v
   b. For how long — 10-15 ma
7. Maximum current available under short circuit conditions — 50 ma
8. System impedance:
   a. Resistive — 5000 ohms
   b. Capacitive
   c. Inductive
9. No. 20-No. 22 wires, twisted pair, insulated — 600 volts.

PROPER SELECTION OF AN ARRESTER

Electrical properties taken into account for proper selection of an arrester are shown in Tables 1 and 2.

INSTALLATION INSTRUCTIONS FOR THE SELECTED ARRESTERS

The installation of the arresters is as important as the selection of the arresters. The wiring from the power system terminals to the arrester terminals should be as short, straight and as large as possible to obtain the desired results. Usually, the manufacturer of the arrester will provide detailed installation instructions which should be followed to the letter.

The limitation of inductive voltages within the equipment operating area is an essential personnel safety measure. Judicious bonding is also required to enable protective devices to achieve their full effectiveness.

Experience has established the desirability of providing a grounding bus around the inside of equipment buildings to facilitate grounding and bonding of equipment enclosures and other metallic objects therein. One form of commonly used bus is a No. 2 AWG copper conductor attached directly to the wall. One ring bus of this type is usually adequate for moderate size buildings without partitions. In larger structures, the use of lateral runs attached to partitions is advisable. Each end of supplemental bus runs should be connected to the main perimeter bus.

TABLE 1—SIGNAL LINES

Protective Device	Nominal D.C. Sparkover Voltage ± 15%	Impulse Sparkover Voltage @ 10KV/µs	Minimum Holdover Voltage	Rated Surge Current 10x20µs Waveshape	Capacitance	Approx. Cost
2001-06	230	730	115V @ 1 amp	5,000 amps	<0.2 PF	$ 1.60
2003-02	L-G 275 L-L 230	L-G 750 L-L 1,000	100V @ 1 amp	40,000 amps	L-G <7.5 PF L-L <5 PF	95.00
2001-89	L-G 175 L-L 300	L-G 800 L-L 1,150	80V @ 1 amp	5,000 amps	L-G <1 PF L-L <.5 PF	4.75
2001-97	L-G 500 L-L 750	L-G 1,100 L-L 1,750	250V @ 1 amp	5,000 amps	L-G <1 PF L-L <.5 PF	4.75

TABLE 2—POWER LINES

Protective Device	Duty	60 Hz RMS Sparkover	Max. Impulse B/D	Max. Discharge Voltage	Life Expectancy	Extreme Duty	Approx. Cost
1201-02	M	175 ± 15%			2,000 @ 10kA	65kA	$330.00
1250-03	L	265 Min.	1,200V	1,320V	50 @ 1.5kA	15kA	52.00
1235-01	M	175 ± 15%	1,200V	1,000V	2,000 @ 10kA	65kA	250.00
1245-01	H	283 ± 15%	1,000V	500V	3,000 @ 10kA	100kA	900.00

The internal ground bus must be effectively connected to the external grounding ring. Several interconnections should be provided, the exact number depending on the dimensions of the building. Buildings having perimeter dimensions up to about 100 feet normally require four interconnections. Larger buildings will require more interconnections, the spacings of which should not exceed 50 feet. In general, these interconnections are arranged in approximately a symmetrical manner; however, the pattern should be such that interconnections are near points where there is a concentration of equipment and where important facilities enter the building such as lines, waveguides, pipes, cables, etc. Incidental objects within a building should also be bonded to the internal ground bus. These would include such items as intake louvers, filter frames, metal doors, and frames.

It cannot be overemphasized that bonding, in spite of its simplicity, is a very effective protection measure for the reduction of hazardous surge voltages. There are two ways inductive voltages associated with the conduction of surge current through a wire can be reduced. One is to reduce the length of the conductor, and the second, and most practical, is to distribute the current over a multiplicity of paths. Opportunity to reduce the length of conductors is limited so the multiplicity of conducting paths provided by the bonding conductors has proven to be a very effective protection measure. Additional benefits are also derived in an actual installation by the many fortuitous bonding paths provided by metallic conduits, cable frames, cable shields, and power grounding conductors. It should not be concluded, however, that the arrangements recommended constitute over-engineering. This type and amount of protection is the result of proven necessity; it has evolved over a period of time from actual field experience.

Bare copper conductors and copper-clad ground rods have been used extensively for the construction of grounds and are still in common use. The durability of these materials has been proven by experience.

When installed indoors and suitably guarded from physical damage, No. 6 AWG copper wire is electrically adequate for bonding and grounding. However, experience has shown that for direct burial in the earth, a No. 2 AWG solid-copper conductor is preferable because of exposure to mechanical stress or damage. A solid conductor should be used because it is less subject to corrosion than a stranded conductor of similar gauge. Within a building, stranded conductors may be used for grounding and bonding since they will not be exposed to corrosion.

Some form of metal fusing, such as Cadwelding, provides an effective and durable means of connecting the components of a grounding system. Pressure connectors sometimes loosen due to cold flow of the conductors.