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Surge protective components: Overview of surge mitigation functions and technologies

Recommendation ITU-T K.96



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Summary

Recommendation ITU-T K.96 presents information on the basic forms of surge mitigation and component technologies available to device and equipment designers. Following this basic Recommendation, further Recommendations in this surge protective components series will describe the applications principles of specific component technologies.

History

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Surge protective components: Overview of surge mitigation functions and technologies

1 Scope

Surge protective components (SPCs) are used in power, telecommunication surge protective devices (SPDs) and equipment ports. This Recommendation gives an overview of:

- surge mitigation functions both non-linear and linear,
- implementing component technologies and characteristics, and
- information on the impulse (surge) generators used to test surge protective components (SPCs), surge protective devices (SPDs) and equipment ports.

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 avalanche breakdown (of a PN junction) [b-IEC 60050-521]: Breakdown that is caused by the cumulative multiplication of charge carriers in a semi-conductor under the action of a strong electric field, which causes some carriers to gain enough energy to liberate new hole-electron pairs by ionization.

3.1.2 bidirectional transistor [b-IEC 60050-521]: Transistor which has substantially the same electrical characteristics when the terminals normally designated as emitter and collector are interchanged.

3.1.3 bipolar junction transistor [b-IEC 60050-521]: Transistor having at least two junctions and whose functioning depends on both majority carriers and minority carriers.

3.1.4 breakdown (of a reverse-biased PN junction) [b-IEC 60050-521]: Phenomenon, the initiation of which is observed as a transition from a state of high dynamic resistance to a state of substantially lower dynamic resistance for increasing magnitude of reverse current.

3.1.5 diode (semiconductor) [b-IEC 60050-521]: Two-terminal semiconductor device having an asymmetrical voltage-current characteristic.

NOTE – Unless otherwise qualified, this term usually means a device with the voltage-current characteristic typical of a single PN junction.

3.1.6 disruptive discharge [b-IEC 60050-212]: Passage of an electric arc following electric breakdown.

3.1.7 disturbance suppression [b-IEC 60050-161]: Action which reduces or eliminates electromagnetic disturbance.

3.1.8 electromagnetic disturbance [b-IEC 60050-161]: Any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter.

NOTE – An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

3.1.9 filter [b-IEEE Std 802.7]: Circuit that selects or rejects one or more components of a signal related to frequency.

3.1.10 forward direction (of a PN junction) [b-IEC 60050-521]: Direction of current that results when the P-type semiconductor region is at a positive voltage relative to the N-type region.

3.1.11 insulation [b-IEC 60664-2-1]: That part of an electrotechnical product which separates the conducting parts at different electrical potentials.

3.1.12 insulation coordination [b-IEC 60664-2-1]: Mutual correlation of insulation characteristics of electrical equipment taking into account the expected micro-environment and other influencing stresses.

3.1.13 isolating transformer [b-IEC 60065]: Transformer with protective separation between the input and output windings.

NOTE – Isolating transformers can be divided into three groups; mains, switched mod and signal (e.g., Ethernet data).

3.1.14 impulse withstand voltage [b-IEC 60664-2-1]: Highest peak value of impulse voltage of prescribed form and polarity applied to a circuit or equipment, which does not cause degradation or result in breakdown or flashover.

3.1.15 low-pass filter [b-IEEE Std 1149.6]: Electrical network that passes lower frequencies, including DC levels, and attenuates higher frequencies.

3.1.16 overvoltage [b-IEC 60664-2-1]: Any voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions.

3.1.17 punch-through (between two PN junctions) [b-IEC 60050-521]: Contact between the space charge regions of two PN junctions as a result of widening of one or both of them.

3.1.18 sparkover [b-IEC 60050-212]: Disruptive discharge in a gaseous or liquid insulating material.

3.1.19 suppression component [b-IEC 60050-161]: A component specially designed for disturbance suppression.

3.1.20 Zener breakdown (of a PN junction) [b-IEC 60050-521]: Breakdown caused by the transition of electrons from the valence band to the conduction band due to tunnel action under the influence of a strong electric field in a PN junction.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

NOTE – Some term definitions, specifically defined for non-linear voltage limiters, are inappropriate for the wide range of mitigation functions covered in this Recommendation. The definitions for these terms have been redefined to make them generic.

3.2.1 band-pass filter: Filter that allows passage of a desired range of frequencies and attenuates frequencies outside the desired range.

NOTE – This definition is based on the definition provided in [b-IEEE Std 802.7].

3.2.2 common-mode choke filter: Series in-line transformer used to mitigate common-mode current flow without affecting differential current flow.

3.2.3 common mode conversion: Process by which a differential mode electrical signal is produced in response to a common mode electrical signal.

NOTE – This definition is based on the definition provided in [b-IEC 60050-161].

3.2.4 common-mode rejection filter: Filter type, usually a balanced filter that attenuates the signal common to both input lines; that signal is called the common-mode signal.

NOTE – This definition is based on the definition provided in [b-IEEE Std 1549].

3.2.5 common-mode surge: Surge appearing equally on all conductors of a group at a given location.

NOTE 1 – The reference point for common-mode surge voltage measurement can be a chassis terminal, or a local earth/ground point.

NOTE 2 – Also known as longitudinal surge or asymmetrical surge.

3.2.6 differential-mode surge: Surge occurring between any two conductors or two groups of conductors at a given location.

NOTE 1 – The surge source maybe be floating, without a reference point or connected to reference point, such as a chassis terminal, or a local earth/ground point.

NOTE 2 – Also known as metallic surge or transverse surge or symmetrical surge or normal surge.

3.2.7 fold-back breakdown (of a bidirectional transistor): Re-entrant breakdown characteristic caused by transistor action producing a region of negative dynamic resistance before reverting back to a low positive dynamic resistance condition.

NOTE – In transistor terms, the initial breakdown is in the BV_{CBO} mode, which changes to the lower voltage BV_{CEO} mode as the breakdown current increases.

3.2.8 high-pass filter: Electrical network that passes higher frequencies, attenuates lower frequencies and blocks DC levels.

NOTE – This definition is based on the definition provided in [b-IEEE Std 1149.6].

3.2.9 neutralizing transformers: Transformers that, through a sensing winding connected to local and remote grounds, introduce a series voltage into a signal circuit pair to oppose differences in local and remote ground potentials and induced common mode voltages.

3.2.10 overcurrent: Any current having a peak value exceeding the corresponding peak value of maximum steady-state current at normal operating conditions.

3.2.11 power fault: Abnormal fault condition, when the local ac power service is in electrical contact (Power Contact) or is magnetically coupled (Power Induction) to another service.

3.2.12 surge: Temporary disturbance on the conductors of an electrical service caused by an electrical event not related to the service.

NOTE – For non-linear SPCs a surge event is defined as an overvoltage or overcurrent or both.

3.2.13 surge protective component (SPC): component specifically included in a device or equipment for the mitigation of the onward propagation of overvoltages or overcurrents or both.

3.2.14 surge protective device (SPD): Device that mitigates the onward propagation of overvoltages or overcurrents or both.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BV_{CBO}	Collector-Base Breakdown Voltage, Emitter Open
BV_{CEO}	Collector-Emitter Breakdown Voltage, Base Open
DC	Direct Current
DSL	Digital Subscriber Line
ECL	Electronic Current Limiter
EMC	Electromagnetic Compatibility
EPR	Earth Potential Rise

FFT	Fast Fourier Transform
GDT	Gas Discharge Tube
GPR	Ground Potential Rise
IC	Integrated Circuit
ICT	Information and Communication Technology
LCR	Inductance, Capacitance Resistance
MOV	Metal-Oxide Varistor
PLC	Power Line Communication
PTC	Positive Temperature Coefficient
SPC	Surge Protective Component
SPD	Surge Protective Device

5 Protection or mitigation or suppression?

The terms "protection" and "protective" are part of the surge protection engineering discipline vocabulary. It should be remembered that these terms imply that, under specified conditions, the surge is reduced to a level below the withstand capability of the following circuit or equipment. However, in the field the incoming surge parameters are the result of many factors, rather than conforming to the standardized impulses from the generators specified in various standards. Likewise the following circuit or equipment withstand can be unknown.

The inclusion of an SPC should reduce the onward level of the incoming surge, but not necessarily to the withstand level of the "protected" item and that withstand level may be unknown. For these reasons the ITU-T prefers to use the term "surge mitigation" (make (something bad) less severe, serious, or painful) instead of "surge protection". If surge protection is achieved then it is a successful case of surge mitigation.

In [b-IEEE Std C62.50] a protection design technique is described for telecom equipment ports that conform to the surge withstand levels of a specific standard. The surge levels applied to the SPC will be greater than that the equipment withstand, otherwise the SPC function is redundant. At these higher levels the surge mitigation should result in an onward open-circuit surge voltage no greater than the equipment surge test generator open-circuit voltage and an onward short-circuit current no greater than the equipment surge test generator short-circuit current. This is an approach that forces a defined level of coordination between the mitigation level and the following equipment withstand.

The electromagnetic compatibility (EMC) area has its own vocabulary as all types of electromagnetic disturbances are considered, not just lightning and power fault and the protective function is termed suppression, see clause 6.2.

6 Surge mitigation functions

6.1 Non-linear protective functions

These functions have a predetermined threshold level beyond which their characteristic changes to limit the surge level. To avoid degrading normal system operation the threshold level set to be higher than the maximum expected system voltage and current. Overvoltages and overcurrents are classified as surge levels that exceed the threshold value of the limiter.

6.2 Linear suppression functions

These functions selectively attenuate electromagnetic disturbances, such as surge, by use of transformer action or frequency selective filtering. These approaches can only be used in specific circumstances.

7 Component technologies and characteristics

7.1 Surge mitigation functions

Figure 1 shows the various types of surge mitigation functions. The left side of the figure shows non-linear functions and the right side shows linear attenuating functions. Some functions can be used to mitigate common-mode and differential-mode surges, while others are limited to differential-mode or common mode surges

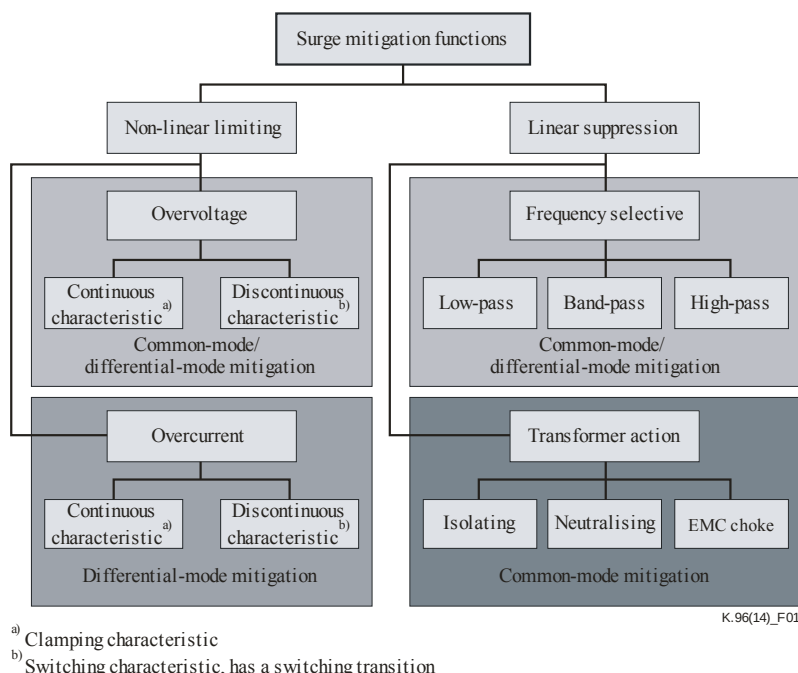


Figure 1 – Common Surge Mitigation Functions

7.2 Non-linear limiting

This form of surge mitigation operates by limiting (clipping) surge amplitudes that exceed a predetermined threshold value to values either close to that of the threshold or much lower than the threshold.

Surge mitigation controlled by an integrated circuit (IC) and a power element can be multimode. For example in a direct current (DC) supply feed using such an arrangement the IC can maintain the conditioned voltage to a fixed level for various combinations of surge voltage and time, but when these combinations are exceeded, the power element is switched off to prevent over-dissipation and the conditioned voltage falls to zero. This sophisticated form of surge mitigation is not covered by this Recommendation.

Gated thyristors, as standardized in [b-IEEE Std C62.37], can be used for individual or combined over-current and overvoltage protection.

7.2.1 Overvoltage limiting

Voltage limiting components draw little current until the voltage exceeds the predetermined threshold voltage of the component.