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SERIES K: PROTECTION AGAINST INTERFERENCE

Principles of protection against overvoltages and overcurrents

Recommendation ITU-T K.11

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Summary

Recommendation ITU-T K.11 deals with protection principles, e.g., risk management, safety and reliability, surge protective devices and surge protective components. It gives guidance for the protection of telecommunication equipment, installations and cable plants exposed to the results of external sources of interference such as overvoltages and overcurrents due to lightning or effects related to power lines and electric traction systems.

It gives general information about:

– the origin of overvoltages and overcurrents (lightning, power induction, power contacts, earth potential rises);
– types of protective devices (voltage-limiting and current-limiting devices) and their residual effects;
– risk assessment;
– protection of telecommunication lines;
– protection of exchange and transmission equipment;
– protection in access networks.

Reference is made, in the bibliography, to some ITU-T K-series Recommendations and IEC standards related to:

– power supply effects and low frequency interference;
– lightning effects;
– surge protective devices and components;
– resistibility of telecommunications equipment.

Source

Recommendation ITU-T K.11 was approved on 13 January 2009 by ITU-T Study Group 5 (2009-2012) under Recommendation ITU-T A.8 procedures.

Keywords

Maintenance, protection, protective measures.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Introduction

Overvoltage protection may be required for safety of persons and for protection of equipment. To provide this protection, it is necessary to interconnect the metallic parts (shield, sheath) along the line and to bond them to the local or building earth, conductors are installed via SPDs at the entrance of the entered structure. This will reduce the risk of injury to people using these services during a.c. fault conditions and during lightning storms. These methods will also provide a level of protection for equipment connected to one or more of these services.

Recommendation ITU-T K.11

Principles of protection against overvoltages and overcurrents

1 Scope

Current ITU-T publications recognize lightning and faults on nearby electrical installations as sources of dangerous disturbances in telecommunication lines, which may cause damage leading to interruptions in service and the need for repairs or even hazards to personnel.

The objective of this Recommendation is to set out principles which enable the frequency and seriousness of such disturbances to be limited to levels which take account of quality of service, operating costs and safety of personnel. These principles are applicable to all parts of a telecommunications system and cover:

– power supply effects and low frequency interference;

– lightning effects;

– surge protective devices and components.

More details on risk calculation, certain methods of protection and protective devices are given in the Recommendations mentioned in the bibliography.

The telecommunication network to be protected using this Recommendation is limited to telecommunication lines using metallic conductors (buried or aerial cables, shielded or unshielded cables, reference configuration, see [ITU-T K.72]). Responsibilities for protection at customer premises are given in [ITU-T K.66].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.66] Recommendation ITU-T K.66 (2004), *Protection of customer premises from overvoltages*.

[ITU-T K.72] Recommendation ITU-T K.72 (2008), *Protection of telecommunication lines using metallic conductors against lightning – Risk management*.

[IEC 61643-1] IEC 61643-1 (2005), *Low-voltage surge protective devices – Part 1: Surge protective devices connected to low-voltage power distribution systems – Requirements and tests*.

[IEC 61643-21] IEC 61643-21 (2009), *Low-voltage surge protective devices – Part 21: Surge protective devices connected to telecommunications and signalling networks – Performance requirements and testing methods*.

ITU-T Recommendations and other documents containing deeper information and provisions, which are relevant to calculate the need of protective measures, the options of protective methods and protective devices are listed in the bibliography.

3 Definitions

This Recommendation defines the following terms:

3.1 active reduction system (ARS): An active reduction system uses a transformer to compensate for induced voltages in the telecommunication cable system. It operates on the basis that, via a transformer, a voltage with a phase shift by 180°, but of the same amplitude, is coupled into the telecommunication cable to be protected. It consists of a coupling element (iron core with a primary winding, a control winding connected to a pilot conductor, a corresponding number of secondary windings) and an amplifier with a power supply.

3.2 inherent protection: Inherent protection is that protection which is provided at an equipment interface either by virtue of its intrinsic characteristics or by specific design.

3.3 maintenance: Combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function.

3.4 multistage protection: Multistage protection is the application of sequential protection stages to achieve the intended overall protection level. The location and level of each stage must be coordinated.

3.5 passive reduction system (PRS): A passive reduction system uses a step-down transformer to compensate for induced voltages in a telecommunication cable system. It consists of an iron core with a primary winding (the grounded cable sheath or a pilot conductor) and a corresponding number of secondary windings. In general, the secondary windings are shielded telecommunication cables.

3.6 pilot conductor: Grounded wire, grounded on both sides of the influenced path to get the steering voltage for the control winding of the active reduction system (ARS) or passive reduction system (PRS).

3.7 primary protection: Primary protection is applied using a surge protective device (SPD) to protect an interface or port of an equipment, at the location where it diverts most of the stressful energy from propagation into the equipment. This SPD must be accessible, removable and connected to equipotential bonding.

3.8 protection coordination: Protection coordination is the act of ensuring that all the protection elements, internal and external to the equipment, react in such a way so as to limit the amount of energy, voltage or current to levels such that damage does not occur to protection elements or equipment.

3.9 resistibility: Resistibility is the ability of telecommunication equipment or installations to withstand, in general, without damage, the effects of overvoltages or overcurrents, up to a certain, specified extent, and in accordance with a specified criterion.

3.10 secondary protection: Secondary protection is applied subsequent to the primary protection. It may be provided by inherent protection.

3.11 surge protective component (SPC): Constituent part of a surge protective device which cannot be physically divided into smaller parts without losing its protective function.

NOTE 1 – This is a modification to definition of item 151-11-21 (component) in the International Electrotechnical Vocabulary [b-IEC 60050-151].

NOTE 2 – The protective function is non-linear; amplitude restriction effectively begins when the amplitude attempts to exceed the predetermined threshold value of the component.

3.12 surge protective device (SPD): Device that restricts the voltage of a designated port or ports, caused by a surge, when it exceeds a predetermined level.

NOTE 1 – An SPD is a combination of a protection circuit and a holder.

NOTE 2 – Secondary functions may be incorporated, such as current limiting to restrict a terminal current.

NOTE 3 – Typically, the protection circuit has at least one non-linear voltage-limiting surge protective component.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ABD Avalanche Breakdown Diode

ARS Active Reduction System

BB Bonding Bar

DSL Digital Subscriber Line

EBB Equipotential Bonding Bar

EMC Electromagnetic Compatibility

GDT Gas Discharge Tube

ISDN Integrated Services Digital Network

ITE Information Technology Equipment

MET Main Earth Terminal

MDF Main Distribution Frame

MOV Metal Oxide Varistor

NT Network Termination

OCP Overcurrent Protector

PRS Passive Reduction System

PTC Positive Temperature Coefficient thermistor

RF Radio Frequency

SOP Semiconductor Overcurrent Protector

SPC Surge Protective Component

SPD Surge Protective Device

TSS Thyristor Surge Suppressor

5 General considerations

When considering protecting a telecommunication network, it is important to determine the probable overvoltage and overcurrent sources and how energy from these sources is coupled into the network, since there are means for reducing the amount of energy coupled into the telecommunication system, the equipment and its installation.

It is reasonable that the electromagnetic environment should be the major dimensioning factor for protection needs. The electromagnetic environment effect is, on one hand, dependent on the type and probability of the occurrence of the electromagnetic phenomena and, on the other hand, on the physical layout of the system.

The protective measures shall not decrease the electromagnetic compatibility (EMC) of the system and shall not degrade its intended function as described in the product standards for the system.

NOTE – EMC means the ability of equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

5.1 Effects related to power lines and electric traction systems

Depending on the physical process, the effects of high voltage power feeding/transforming or traction systems on a telecommunication system can be divided into:

– capacitive coupling which represents the effect of an electric field (electric induction);

– inductive coupling which represents the effect of a magnetic field (magnetic induction);

– conductive coupling which represents the effect of a conduction field due to current in the earth.

These effects may contain multiple components, mainly inductive and conductive coupling. Telecommunication systems with dense electrical integration will be more liable to direct damage due to the reduced creepage distances and clearances.

For a broad understanding of telecommunication, power and electrified railway facilities, and their mutual coupling effects, consult [b-Handbook II] and [b-Handbook VI].

5.1.1 Induction from fault currents

Induction from fault currents (earth faults) in power lines, including electric traction systems, causes large unbalanced currents to flow along the power line inducing overvoltages into adjacent telecommunication lines which follow a parallel course. The overvoltages may rise to several kilovolts and have durations of 200 to 1000 ms (occasionally even longer) depending on the fault clearing system used on the power line.

5.1.2 Contact with power lines

Contact between power and telecommunication lines may occur when local disasters, e.g., storms, fires, cause damage to both types of plant or when the normal safeguards of separation and insulation are not followed. Overvoltages from direct contact of overhead lines rarely exceed 230 V a.c. r.m.s. in countries where this is the common distribution voltage, but may continue for an indefinite period until observed. Where higher distribution voltages (e.g., 2 kV) are used, the power line protection arrangements usually ensure that the voltage is removed in a short time if a fault occurs. The overvoltage may cause excessive currents to flow along the line to the exchange earth causing damage to equipment and danger to staff.

5.1.3 Rise of earth potential

Earth faults in power systems cause currents in the soil which raise the potential in the neighbourhood of the fault and of the power supply earth electrode. These earth potentials may affect telecommunication plants in two ways:

a) For crossbar switches and equipment whose metallic lines take the ground as their loop, telecommunication signalling systems may malfunction if their earth electrodes are in soil whose potential rises by as little as 5 V with respect to true earth. Such voltages may be caused by minor faults on the power system which may remain undetected for long periods. However, for stored program control switches and equipment taking optical fibre cable as their loop, it is not required to consider the interference caused by potential rise due to faults on the power system.

   NOTE – Such effects of potential rise on program control switches are different from on the crossbar switches and equipment taking the ground as their loop. Adopting optical fibre cables as the media between program control switches avoids interference due to possible potential difference when the metallic lines take the ground as their loop.

b) Higher rises of earth potential can cause danger to staff working in the affected area or, in extreme cases, may be sufficient to break down insulation of the telecommunication cable, causing extensive damage.

5.2 Effects related to lightning effects

5.2.1 Direct lightning strikes

Such strikes may cause currents of some thousands of amperes to flow along wires or cables for some microseconds. Physical damage may occur and overvoltage surges of many kilovolts may apply stress to the dielectrics of line plant and terminal equipment.

5.2.2 Lightning strikes nearby

Lightning currents flowing from cloud to earth or cloud to cloud cause overvoltages in overhead or underground lines near to the strike. The area affected may be large in districts of high earth resistivity.

5.3 Methods of protection

The telecommunication network can be endangered by atmospheric discharge, power influence and power cross. Protective measures must be coordinated with the system to be protected. Protection of the telecommunication network and its service is achieved by following fundamental protection methods:

– Earthing: Reliable electrical connection of the system with a conductor that provides a low impedance path to the earth (ground) to prevent hazardous voltages from appearing on equipment. Normally, a grounding conductor does not carry current.
– Equipotential bonding: Electrical connection putting various exposed conductive parts and extraneous conductive parts at a substantially equal potential. It is orientated to reduce the earth potential difference between different metallic conductors, equipment and circuits in the case of faults or external interference (such as lightning strike).
– Shielding: Shielding is the process of limiting the flow of electromagnetic fields between two locations, by separating them with a barrier made of conductive material. Typically, it is applied to enclosures, separating the system from the electrical environment. Shielding used to block radio frequency electromagnetic radiation is also known as RF shielding.
– Improving insulation strength: Improvement of the insulation level of the equipment and lines to prevent overvoltage from damaging insulation so as to ensure equipment and personal safety.
– Disconnection: Allocation of the line with a fuse, resettable OCP (PTC, SOP) or switch facility to prevent excessive energy from entering sensitive circuits.
– Current distribution: Installation of an SPD between the lines and/or between lines and earth. SPDs restrict the voltage of a designated port or ports, caused by a surge, when it exceeds a predetermined level. The decision to use surge protective devices (SPDs) is most properly based on an analysis of the risks that are seen by the network or system under consideration.
– Counter voltages: Counter voltages are used to compensate for induced voltages.

Some of the protective measures for lines which are described in clause 6 have the effect of reducing overvoltages and overcurrents at their source and so reduce the risk of damage to all parts of the system.

Other protective measures which may be applied to specific parts of the system, as indicated in clauses 6, 7 and 8, can be separated into two classes:

– the use of protective devices which prevent excessive energy from reaching vulnerable parts either by diverting it (for example, spark gaps) or by disconnecting the line (for example, fuses);
– the use of equipment with suitable dielectric strength, current-carrying capacity and impedance so that it can withstand the conditions applied to it.

5.4 Surge protective devices and surge protective components

When considering the application of protective devices and components to a telecommunication system, the probable overvoltage and overcurrent sources, and how energy from these sources is coupled into the network, have to be identified by risk assessment and/or experience.

Primary and secondary protection should always be coordinated correctly. To ensure that two cascaded SPDs or SPCs and a following SPD or the telecommunications system are coordinated, it might be necessary to select primary protection and secondary protection (or multistage protection) to ensure that the inherent protection of the system is not exceeded (see clause 5.7.6).

5.4.1 Gas discharge tubes

Usually, GDTs are used as primary protection connected between each wire of a line and earth or as 3-electrode units between a pair and earth. Their performance may be specified to precise limits to meet system requirements. GDTs operate frequently without degradation if not overloaded.

In case of direct contact between power lines and telecommunication lines, the GDT might be stationary ignited. To prevent this, the GDT might offer a failsafe function whereby heating is detected by a mechanism that is thermally initiated to short-circuit the electrodes of the GDT.

NOTE – Air-gap protectors with carbon or metallic electrodes are usually connected between each wire of a line and earth, they limit the voltage which can appear between their electrodes. They are inexpensive but their insulation resistance can fall appreciably after repeated operation and they may require frequent replacement. For that reason, they are nowadays uncommon.

5.4.2 Semi-conductor protective devices

Semi-conductor protective devices are usually used as secondary protection, but developments in the technology of these devices have produced some units which may be used as primary protection. Semi-conductor protective devices operate frequently without degradation if not overloaded.

5.4.3 Varistor

Usually connected between each wire of a line and earth or across the wires, varistors are nonlinear two-electrode voltage-dependant resistors, whose resistance decrease with increasing voltage. Varistors operate frequently with degradation after repeated transient events.

5.4.4 Fuses

Fuses are connected in series with each wire of a line to disconnect when excessive current flows. Simple fuses have a uniform wire which melts. Slow-acting fuses have a uniform wire which melts quickly when a large current flows, and a spring-loaded fusible element which melts gradually and disconnects when lower currents flow for a prolonged time. High level currents of 2 A and prolonged currents of 250 mA are typical operating levels. Fuses should not sustain an arc after operation. Fuses do not give protection against lightning surges and, in districts where such surges are common, fuses of a high rating (up to 20 A) may be necessary to avoid trouble from fuse failures. Such fuses may not give adequate protection against power line contacts. Fuses can also be a source of noise and disconnection faults. Fuses permanently interrupt a circuit when operated and it is necessary to replace them manually.

5.4.5 Heat coils

Heat coils are connected in series with each wire of a line. Heat coils either disconnect the line, earth it, or do both, with the earth extended to line. Heat coils have some fusible component and operate when currents of, typically, 500 mA flow for some 200 s. Heat coils permanently interrupt a circuit when operated and it is necessary to replace them manually.

5.4.6 Fusible links

Fuseless overvoltage protector assemblies installed on telecommunication lines can be protected against the risk of overheating in the event of a prolonged contact between the telecommunication line and a power distribution line by means of a fusible link.

A fusible link usually consists of insulated conductors in series with the telecommunication line and located between the exposure to the power line and the protector assembly. The conductors are usually at least two wire gauges smaller than the conductors terminated on the protector assembly and are of a suitable length to avoid a sustained arc if the power system does not de-energize promptly and the conductors fuse. If the fusible link, or part of it, is installed in a building or other location where a fire hazard might occur, it is enclosed within a cable sheath, splice enclosure or other suitable enclosure to contain any arcing that may result if the conductors fuse.

5.4.7 Overcurrent protectors

Overcurrent protectors (OCPs) are placed in series with each wire of a line and operate to limit excessive a.c. currents as an open circuit. There are variable impedance devices which, when heated by overload currents, increase their electrical resistance to a very high value. When the overload is removed, the devices will return to their normal condition and permit operation of the line.

5.5 Residual effects

The essential purpose of protective measures is to ensure that the major part of the electrical energy arising from a disturbance is not dissipated in a vulnerable part of the installation and does not reach personnel. However, no device exists which has characteristics for suppressing ideally all voltages or currents connected with disturbances, for the following reasons.

5.5.1 Residual overvoltages

Account should be taken of:

a) voltages which are unaffected by the protective device because they are below its operating level;

b) transients which pass before the device operates;

c) residuals which are sustained after the device operates;

d) transients produced by the operation of the device.

5.5.2 Transverse voltages

Protective devices on the two wires of a pair may not operate simultaneously and so a transverse pulse may be produced. Under certain conditions, particularly if the equipment to be protected has a low impedance, operation of one protective device may prevent the operation of the other one and a transverse voltage may remain as long as the longitudinal voltages are on the line.

5.5.3 Effect on normal circuit operation – Coordinated design

Sufficient separation should be allowed between the operating voltage of the protective devices and the highest voltage occurring on the line during normal operation.

Likewise, the normal characteristics (internal impedances) of the protective elements must be compatible with the normal functioning of the installations, which must take account of their possible presence.

5.5.4 Modifying effects

SPDs may safeguard one part of a line at the expense of another, e.g., if an MDF fuse operates due to a power line contact, the voltage on the line may rise to full power line voltage when the fuse disconnects the telecommunication's earth.

Likewise, the operation of an SPD may greatly reduce the equivalent internal impedance of a circuit relative to equipment connected to it, thus permitting the circulation of currents which may cause damage.

5.5.5 Protection coordination

For the protection of sensitive equipment, it is sometimes necessary to use more than one protective device, e.g., a fast-operating, low-current device such as a semiconductor and a slower-operating, high-current device such as a gas discharge tube. In such cases, steps must be taken to ensure that, in the event of a sustained overvoltage, the low-current device does not prevent the operation of the high-current device since, if this happens, the smaller device may be damaged, or the interconnecting wiring may conduct excessive current.

5.5.6 Temperature rise

SPCs or SPDs should be designed and positioned in such a way that the rise in temperature which occurs when they operate is unlikely to cause damage to property or danger to people.

5.5.7 Circuit availability

The circuit being protected may be temporarily or permanently put out of service when a protective device operates.

5.5.8 Fault liability

The use of SPDs may cause maintenance problems due to unreliability. They may also prevent some line and equipment testing procedures.

5.6 Risk management

The need for protective measures (e.g., protection with SPDs) should be based on a risk assessment considering the probability of overvoltage and overcurrent. The assessment of all parts of the network shall attain a well-coordinated protection of the whole network. This takes into account the consequences of the loss of service for the customer and the network operator, the importance of the system (e.g., hospitals, traffic control), the electromagnetic environment at the particular site (probability of damages) and the cost related to repair.

5.6.1 Assessment of risk

The performance of a telecommunications system with respect to overvoltages depends on:

– the environment, i.e., the magnitude and probability of overvoltages occurring in the line network associated with the system;
– the construction methods used in the line network, see clause 6;
– the resistibility of equipment in the system;

– the provision of protective devices;
– the quality of the earth system provided for the operation of the protective devices.

The above aspects have to be taken into account to assess the risk.

5.6.2 Sources of damage

In assessing the environment, consideration should be given to the effects mentioned in clauses 5.1 and 5.2.

The severity of overvoltages due to lightning varies widely in different localities. A high keraunic level and a high soil resistivity increase the risk of direct and nearby lightning strokes. Lightning is the cause of a large proportion of power system faults, induction and rise of earth potential effects are also increased. On the other hand, buried metal plant, such as water pipes, armoured cables, etc., screens telephone cables greatly reduces overvoltages due to lightning or induction.

– In city centres and in regions of low keraunic activity, experience shows that overvoltages rarely exceed the residual voltages of protective devices and such environments may be classified as "unexposed". Product Recommendations (listed in the bibliography) specify "basic test levels" to be applied to equipment for use in unexposed environments without protection, and these tests give an indication of the most severe environment which can be regarded as unexposed.
– All other environments are classified as "exposed" but this, of course, covers a wide range of conditions including exceptionally exposed situations where a satisfactory service can only be achieved by the use of all available protective measures. Product Recommendations (listed in the bibliography) specify "enhanced test levels" applied to equipment for use in exposed environments.

In the case of induced voltages and rise of earth potential, the overvoltages can be calculated with the documents indicated in the bibliography (i.e, those that relate to power supply effects and low frequency interference, and lightning effects) which also recommend the maximum values which may be permitted under various conditions.

5.6.3 Fault records

The risk of overvoltages and overcurrents might be assessed in the light of experience. It is recommended that fault statistics be kept in a form which is convenient for that purpose. Faults due to overvoltages or overcurrents and faults due to failures of protective components should be separated from each other and from other component faults.

5.7 Protection principles

5.7.1 Safety principle

Protection devices should be able to prevent such faults as fire hazards and/or large-scale communication interruption due to extension of the negative effects of the damage to telecommunication equipment, so as to limit the faults within a range acceptable to operators.

When designing, installing and using protective devices, it is required to take it into consideration that the temperature rise due to enabling them should not be high enough to damage their attributes or endanger personal safety.

Radioactive materials or other harmful materials must not be adopted for protective devices.

5.7.2 Reliability principle

Effective protection should be realized within a specified reaction time, and for a specified duration, when the protective devices are exposed to the overvoltage and overcurrent conditions described in this Recommendation. Unreliable protection devices may affect communication as well as maintenance and testing for some lines and equipment.

5.7.3 Availability principle

Designing, installing and using protection devices should not affect normal running of the equipment under protection. The signal loss during transmission and impedance should be limited to a specified range. In addition, convenient installation, maintenance and replacement should be ensured for protective devices, and the effect on other telecommunication lines should be as little as possible.

The non-operating current of second level overcurrent protection should be less than that of first level overcurrent protection.

5.7.4 Economy principle

The appropriate protection level and economic technical scheme should be selected on the basis of safety and reliability.

Since any device itself may be the origin of faults, adopting inappropriate protection devices and circuits for excessive protection is not only very wasteful, but also can attenuate system performance.

5.7.5 Principle of hierarchical protection

Based on safety and economy principles, determine whether to adopt basic protection (second level protection) only or enhanced protection (including both first and second level protection).

5.7.6 Coordination principle

To ensure that two cascaded SPDs, or an SPD and an information technology equipment (ITE) to be protected, are coordinated during overvoltage conditions, the output protective levels from the SPD shall not exceed the input resistibility levels of the followed SPD or the ITE for all known and rated conditions.

For example, the second level SPD adopts small current devices with fast operation (such as semiconductor protective devices), while first level SPD adopts strong current devices with slower operation (such as gas discharge tubes). In this case, coordination is required to prevent the second level SPD from affecting the operation of first level SPD, as well as from being damaged by overcurrent.

For overcurrent protection, the output current upon the operation of first level overvoltage protection should be lower than the non-operating current. Besides, the current-limit operation time for the first level overcurrent protection should be less than that of the second level overcurrent protection.

Normal telecommunication conditions should be appropriately maintained during the implementation of protection circuits or devices.

5.8 Decision on protection

In considering the degree to which a telecommunication network should withstand overvoltages, two classes of failure may be recognized:

– Minor failures affecting only small parts of the system. These may be allowed to occur at a level acceptable to the administration.

– Major breakdowns, fires, exchange failures, etc., which must, so far as possible, be avoided completely.

Examples of conditions which may be permitted to cause minor failures but not major breakdowns are given in the product Recommendations (listed in the bibliography). It is desirable also that failure of a single protective device should not cause a major breakdown. Particular attention should be given to overvoltage and overcurrent protection for new types of exchange or customer equipment to ensure that the benefits of its improved facilities are not lost due to unacceptable failures arising from exposure to overvoltages or overcurrents. Such equipment may be inherently sensitive to these conditions and damage or malfunction may affect large parts of a system. It should be noted that over-protection, by the provision of unnecessary protective devices, is not only uneconomic but may actually worsen system performance since the devices themselves may have some liability to cause failures.

To avoid disturbances in telecommunication circuits caused by activated protective devices, the striking voltage values and the numbers of arresters should be considered.

In the light of the above considerations and the assessment of risks in accordance with clause 5.6.1, a decision should be made on the protection to be provided in all parts of the system. Account should be taken of commercial considerations such as the cost of protective measures, the cost of repairs, relations with customers and the probable frequency of faults due to overvoltage and overcurrent relative to the fault rate due to other causes.

The responsibility for making this decision and for ensuring the provision of any protective devices needed to coordinate lines and equipment should be clearly laid down.

It is necessary for manufacturers of equipment to know the conditions that the equipment will need to resist and for line engineers to know the resistibility of the equipment which will be connected to the lines. The line engineer should also define the constraints which equipment connected to the line will encounter, depending on the standards of line protection provided. Where parts of the network, such as equipment installed in customer premises, lines and telecommunications centres may be under different ownership, this coordination may require formal procedures such as the production of local standards. The Recommendations listed in the bibliography that are related to resistibility of telecommunications equipment give guidance for the preparation of these standards.

6 Protection of telecommunication lines

The general considerations of clauses 5.5 and 5.7 apply to the protection of telecommunication lines. It is highly recommended that the protective measures applied to the line should be decided at the outset of a project and should depend on the environment. It may be difficult and expensive to achieve a satisfactory standard of reliability from a line provided initially with insufficient protection.

Where lines in a telecommunication network are exposed to frequent or severe disturbances from power line faults or lightning, the voltage of these lines relative to local earth potential should be limited either by connecting protective devices between the line conductors and earth or by using appropriate construction methods for the line.

6.1 Protective measures external to the conductors themselves

Telecommunication lines may be shielded from lightning and power induction to some extent by adjacent earthed metal structures, e.g., power lines or electric railway systems. Efficient metallic screens either in the form of cable sheaths, cable ducts or lightning guard wires, reduce the effects of lightning surges and power line induction. It is necessary to point out that these metal structures, like the screen of the cable, shall be continuous and connected across all splices along the length of the cable, and shall be connected to the BB, preferably directly or through an SPD (to avoid corrosion problems), at the ends of the cable.

Induction from power lines may be minimized by coordinating the construction practices for the power and telecommunication lines. The level of induction may be reduced at its source by the installation of earth wires and current limiters in the power system.

The likelihood of contacts occurring between power lines and telecommunications lines is reduced if agreed standards of construction, separation and insulation are followed. Economic considerations arise, but it is often possible to benefit from jointly using trenches, poles and ducts, providing suitable safe practices are adopted.

Installing buried telecommunication lines instead of an aerial will halve the risk of damage due to overvoltages.

6.2 Special cables and protective systems

Standard plastic insulated and sheathed cables have a higher dielectric strength than paper-insulated, lead-sheathed cables and are suitable for most situations where cables with extra thick insulation were formerly used. The use of cables with strengthened insulation may be justified in situations where there is exceptional proximity or length of parallelism to power lines, high rise of earth potential in the immediate neighbourhood of power stations, or extreme exposure to lightning due to high keraunic level and low soil conductivity.

Examples of special cables and protective systems are:

– cables with metal sheaths which provide a good reduction factor to screen circuits within the cable;
– cables which carry circuits to exposed radio towers and which must be able to carry lightning discharge currents without damage;
– all-dielectric (i.e., non-metallic) optical fibre cables to affect isolation between conductive lengths of cable;
– active or passive reduction systems (ARS, PRS).

6.3 Use of protective devices

The use of protective devices may be desirable in the following circumstances.

They may be more economical than the special construction described in clauses 6.1 and 6.2. In this regard, the cost of maintenance should not be overlooked since protective devices inevitably incur some maintenance expenditure whereas special cables, screening, etc., though initially expensive, usually incur no continuing costs.

Cables with extra thick insulation may themselves be undamaged by overvoltages or overcurrents, but they can nevertheless conduct such conditions to other more vulnerable parts of the network. Extra protection is then required for the more vulnerable cables, which is particularly important if these are large underground cables which are expensive to repair and affect service to many customers.

Induced overvoltages from power or traction line faults may still exceed levels permitted by the Directives (see bibliography entries that relate to power supply effects and low frequency interference) even after all practicable avoidance measures have been followed.

6.4 Installation of protective devices

To protect conductor insulation, it is beneficial to bond all metal sheaths, screens, etc., together, and to connect overvoltage protectors between the conductors and this bonded metal which should be connected to earth. This technique is particularly useful in districts of high soil resistivity as it avoids the need for expensive electrode systems for the protector-earth connection.

Where protectors are used to reduce high voltages appearing in telecommunication lines due to induction from power line fault currents, they should be fitted to all wires at suitable intervals and at both ends of the affected length of line, or as near to this as practicable.

To protect underground cables against lightning surges, protective devices may be placed at the points of connection to overhead lines. The protective devices fitted at the MDF and at customers' terminals reduce the risk of damage to lines, but their main function is to protect components having lower dielectric strength than the cables.

Connections for lines and earth to overvoltage protectors used against lightning should be as short as possible to minimize surge voltage levels between lines and the equipotential bond point.

7 Protection of exchange and transmission equipment

7.1 Need for protection external to the equipment

Network operators should take account of the possible need to fit protection external to the equipment, bearing in mind the considerations given below.

A telecommunication line will give some protection to equipment under certain conditions, e.g.:

– a conductor may melt and disconnect an excessive current;

– conductor insulation may break down and reduce an overvoltage;

– air-gaps in connection devices may break down and reduce overvoltages.

The robustness of plastic insulated cables has the effect of increasing the levels of overvoltages and overcurrents which can occur in the lines and be applied to equipment. By contrast, the use of miniature electronic components in telecommunication equipment tends to increase its vulnerability to electrical disturbances.

For these reasons, in districts exposed to frequent and serious disturbances (lightning, power lines, soil of low conductivity), it is usually necessary to interpose protective devices of the types described in clause 5.4 between the cable conductors and the equipment to which they are connected, preferably on the MDF. This will prevent cables from the MDF to equipment from having to carry heavy overcurrents.

The protective devices are fitted to the line side of the MDF to avoid the need to carry discharge currents in the MDF jumper field and to expose as little of the MDF wiring and terminal strips as possible to mains voltage in the event that a mains voltage line contact causes a series protective device to disconnect the line.

In less exposed locations, it may be that disturbances (voltages and currents) have statistical characteristics of level and frequency so low that in practice the risks do not exceed those resulting from the residual effects indicated in clause 5.5 for exposed regions. Protective devices then serve no purpose and are an unnecessary expense.

7.2 Need for equipment to have a minimum level of electrical robustness

In locations where lines are exposed and protective devices are provided, the residual effects can cause overvoltages and overcurrents to appear in the equipment. In less exposed environments, the disturbances described in clause 7.1 can cause similar effects. It is necessary for equipment to be designed to withstand these conditions, and detailed Recommendations on the resistibility which telecommunication equipment should possess are listed in the bibliography.

7.3 Effect of switching conditions

Since the configuration and interconnection of equipment connected to a given line is required to vary during the successive stages of connecting a call, it is important not to limit the study of protection solely to individual line equipment. Much equipment is common to all lines and can be exposed to disturbances when connected to a particular line.

The effectiveness of the protection provided can be influenced by the reduction in the probability of exposure if the effective duration of the connection to lines is short. On the other hand, common equipment should be better protected since its failure risks more serious degradation in the performance of the service.

8 Protection in access networks

The increasing use and interconnection of complex electronic telecommunication equipment, such as ISDN terminals, modems and computers, at customers' buildings and xDSL equipment in curbs, requires special care for protecting against overvoltages and overcurrents. Such overvoltages and overcurrents include exposure of the serving telecommunication cable and power line to lightning, and the coupling of a.c. voltages onto the telecommunication cable due to faults on the external power system. Properly configured equipotential bonding within the structure helps to achieve the necessary protection, while also helping to ensure the safety of those using the equipment.

It is reasonable that the electromagnetic environment should be the major dimensioning factor for protection needs, and not its ownership. The electromagnetic environment effect is, on one hand, dependent on the type and probability of the occurrence of the electromagnetic phenomena and, on the other hand, on the physical layout of the equipment installation.

8.1 Degree of exposure

Lines to installations near exchanges in urban or industrial zones are usually little exposed to surges on account of the screening effect of numerous nearby metallic structures as described in clause 6.1.

On the other hand, lines to installations remote from built-up areas can be very exposed on account of their length, the absence of a protective environment, overhead construction at the customer's end and the high resistivity of the soil. The mechanical robustness of the overhead cables at the customer's end makes the effect of surges all the more serious since the line itself can carry higher voltages and currents.

8.2 Use of SPDs and SPCs

8.2.1 Use of voltage limiting devices

Where telecommunication lines are exposed to frequent and severe disturbances from power line faults or lightning, the voltage of the lines relative to local earth potential should be limited by connecting SPDs or SPCs between the line conductors and the earth terminal, see clause 5.4.

The terminal equipment dielectric strength should be chosen taking account of the breakdown voltage of the protective device and the impedance of the protector line to earth connection.

8.2.2 Use of high voltage isolation devices

Where protected telecommunication lines:

1) exhibit excessive trouble reports due to lightning activity; or

2) cannot have overvoltage or overcurrent protection installed for whatever reason; or

3) when access to the premises by plant maintenance personnel is difficult;

then high voltage (up to 50 kV) isolation, together with other suitable measures such as protection to be applied at the drop point from the telecommunications cable, may well be considered.

The isolation elements should be installed as close as possible to the customer premises on the outside. They must not be mounted inside buildings.

Isolation techniques may also be helpful at the telecommunication input to high voltage plant (for example, by means of isolation transformers), and in other situations where communications are vital and high plant voltages are probable.

8.2.3 Multiservice surge protective devices

Multiservice surge protective devices consist of a combination of protection circuits in a single enclosure for at least two different services (e.g., telecommunication and power supply), which limits the surge voltages to the equipment and provides equipotential bonding between the different services. The surge voltage protection circuits of combined protective devices shall comply with the requirements of [IEC 61643-1] for the power supply circuit, and with [IEC 61643-21] for the telecommunications/signalling circuits.

8.3 Equipotential bonding

Overvoltage protection has been required for terminal equipment that has been traditionally under the network operators' responsibility. Due to liberalization in telecommunications, the customer may now own this type of equipment. Electrical installations of buildings are a part of the protection for safety and are under the responsibility of the building owner, this includes the existence of EBB to achieve effective protection. The responsibilities for protective measures are now shared between the network operator and the customer. Most of the practices required to achieve effective protection are beyond the control of the network operator. This may be the responsibility of other parties, e.g., the building owner or the customer.

In some countries, connection to the electricity system neutral is governed by national regulations, so that agreement with the electrical authority should be obtained.

In the course of the maintenance of the telecommunication plant, equipotential bonding (connection to the EBB or MET) has to be inspected.

8.4 High isolation techniques

When telecommunication lines are located in areas with a very high level of exposure to lightning (frequent breakdowns on lines and also high probability on the terminal installations) and when lightning protectors cannot be installed on the customer plant owing to earthing and maintenance difficulties and costs, it is recommended to employ a high isolation technique (of a level of at least 20 kV) at the telephone line access by transformer isolator or short fibre links.

This method should be widely introduced at the input to high-voltage plant and is strongly recommended.

8.5 National regulations

Many countries have national standards covering the protection of users of telecommunication equipment not only from the risks associated with connection to the electricity mains but also from conditions which may appear on the telecommunication line.

8.6 Maintenance of installations

The maintenance requirements of customer installations may be high by reason of the distance from the maintenance centre, transport delays and, possibly, the seriousness of the damage. Moreover, insufficient protection is the cause of repeated interruptions of service which are particularly damaging to the quality of service and to the satisfaction of the customer. This justifies the granting of special attention to the maintenance of the protective measures that might become necessary in the following cases:

– repeated appearance of damage caused by electrical sources;

– later erection of exposed structures;

– later erection or changes of electric power plants/traction systems;

– change of the operating currents in existing power plants/traction systems;

– customer or authority request.

The maintenance of the interconnection of cable screens and the earthing of the screen at both ends, including equipotentialization of the system together with remote steerable protective systems, is seen as the most effective measure to reduce maintenance costs.

Bibliography

[b-ITU-T Guide] ITU-T Reference Document (2008), *Guide to the use of ITU-T publications produced by Study Group 5 aimed at achieving electromagnetic compatibility and safety*.

ITU-T Recommendations related to power supply effects and low frequency interference

[b-ITU-T K.5] Recommendation ITU-T K.5 (1988), *Joint use of poles for electricity distribution and for telecommunications*.

[b-ITU-T K.6] Recommendation ITU-T K.6 (1988), *Precautions at crossings*.

[b-ITU-T K.8] Recommendation ITU-T K.8 (1988), *Separation in the soil between telecommunication cables and earthing system of power facilities*.

[b-ITU-T K.9] Recommendation ITU-T K.9 (1988), *Protection of telecommunication staff and plant against a large earth potential due to a neighbouring electric traction line*.

[b-ITU-T K.13] Recommendation ITU-T K.13 (1988), *Induced voltages in cables with plastic-insulated conductors*.

[b-ITU-T K.14] Recommendation ITU-T K.14 (1988), *Provision of a metallic screen in plastic-sheathed cables*.

[b-ITU-T K.19] Recommendation ITU-T K.19 (1988), *Joint use of trenches and tunnels for telecommunication and power cables*.

[b-ITU-T K.26] Recommendation ITU-T K.26 (1988), *Protection of telecommunication lines against harmful effects from electric power and electrified railway lines*.

[b-ITU-T K.29] Recommendation ITU-T K.29 (1992), *Coordinated protection schemes for telecommunication cables below ground*.

[b-ITU-T K.50] Recommendation ITU-T K.50 (2000), *Safe limits of operation voltages and currents for telecommunication systems powered over the network*.

[b-ITU-T K.54] Recommendation ITU-T K.54 (2004), *Conducted immunity test method and level at fundamental power frequencies*.

[b-Handbook II] ITU-T Handbook (1999), *Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines; Volume II: Calculating induced voltages and currents in practical cases*.

[b-Handbook VI] ITU-T Handbook (2008), *Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines; Volume VI: Danger, damage and disturbance*.

[b-Handbook VII] ITU-T Handbook (1989), *Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines; Volume VII: Protective measures and safety precautions*.

ITU-T Recommendations related to lightning effects

[b-ITU-T K.25] Recommendation ITU-T K.25 (2000), *Protection of optical fibre cables*.

[b-ITU-T K.29] Recommendation ITU-T K.29 (1992), *Coordinated protection schemes for telecommunication cables below ground*.

[b-ITU-T K.39] Recommendation ITU-T K.39 (1996), *Risk assessment of damages to telecommunication sites due to lightning discharges*.

[b-ITU-T K.40] Recommendation ITU-T K.40 (1996), *Protection against LEMP in telecommunications centres*.

[b-ITU-T K.46] Recommendation ITU-T K.46 (2008), *Protection of telecommunication lines using metallic symmetric conductors against lightning-induced surges*.

[b-ITU-T K.47] Recommendation ITU-T K.47 (2008), *Protection of telecommunication lines using metallic conductors against direct lightning discharges*.

[b-ITU-T K.56] Recommendation ITU-T K.56 (2003), *Protection of radio base stations against lightning discharges*.

[b-ITU-T K.57] Recommendation ITU-T K.57 (2003), *Protection measures for radio base stations sited on power line towers*.

[b-ITU-T K.67] Recommendation ITU-T K.67 (2006), *Expected surges on telecommunications and signalling networks due to lightning*.

[b-ITU-T Lightning] ITU-T Handbook (1994), *The Protection of Telecommunication Lines and Equipment Against Lightning Discharges*.

ITU-T Recommendations related to surge protective devices and components

[b-ITU-T K.12] Recommendation ITU-T K.12 (2006), *Characteristics of gas discharge tubes for the protection of telecommunications installations*.

[b-ITU-T K.28] Recommendation ITU-T K.28 (1993), *Characteristics of semi-conductor arrester assemblies for the protection of telecommunications installations*.

[b-ITU-T K.30] Recommendation ITU-T K.30 (2004), *Self-restoring overcurrent protectors*.

[b-ITU-T K.36] Recommendation ITU-T K.36 (1996), *Selection of protective devices*.

[b-ITU-T K.55] Recommendation ITU-T K.55 (2002), *Overvoltage and overcurrent requirements for insulation displacement connectors (IDC) terminations*.

[b-ITU-T K.65] Recommendation ITU-T K.65 (2004), *Overvoltage and overcurrent requirements for termination modules with contacts for test ports or SPDs*.

[b-ITU-T K.69] Recommendation ITU-T K.69 (2006), *Maintenance of protective measures*.

[b-Handbook VIII] ITU-T Handbook (1989), *Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines; Volume VIII: Protective devices*.

NOTE – ITU-T is considering the publication of guidance on the application of protective devices and/or components in telecommunication installations.

Other documents related to surge protective devices and components

[b-IEC 61643-311] IEC 61643-311 (2001), *Components for low-voltage protective devices – Part 311: Specification for gas discharge tubes (GDT).*

[b-IEC 61643-321] IEC 61643-321 (2001), *Components for low-voltage protective devices – Part 321: Specification for avalanche breakdown diode (ABD).*

[b-IEC 61643-331] IEC 61643-331 (2003), *Components for low-voltage surge protective devices – Part 331: Specification for metal oxide varistors (MOV).*

[b-IEC 61643-341] IEC 61643-341 (2001), *Components for low-voltage surge protective devices – Part 341: Specification for thyristor surge suppressors (TSS).*

ITU-T Product Recommendations related to resistibility of telecommunications equipment

[b-ITU-T K.20] Recommendation ITU-T K.20 (2003), *Resistibility of telecommunication equipment installed in a telecommunications centre to overvoltages and overcurrents*.

[b-ITU-T K.21] Recommendation ITU-T K.21 (2003), *Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents*.

[b-ITU-T K.44] Recommendation ITU-T K.44 (2003), *Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation*.

[b-ITU-T K.45] Recommendation ITU-T K.45 (2003), *Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents*.

Other documents on general topics

[b-IEC 60050-151] IEC 60050-151 (2001), *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*.

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