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Recommendation K.19

JOINT USE OF TRENCHES AND TUNNELS FOR TELECOMMUNICATION AND POWER CABLES

(Geneva, 1980)

1 General

The joint use of trenches and tunnels for telecommunication and power cables may, under favourable conditions, offer the following advantages:

— the overall costs are reduced;

— available space for underground services is used more efficiently;

— there is a reduced amount of roadway surfacing work and consequently less delay to traffic;

— the separation of power and telecommunication cables is more precisely assured.

2 Electrical safety

If power and telecommunication cables are not easily distinguished from each other they should be clearly marked.

Power cables should generally be buried deeper than telecommunication cables.

Power and telecommunication cables should be separated by a suitable distance according to:

a) the voltage of the power cable;

b) the type of the power cable;

c) the type of the telecommunication cable;

d) the nature of the separating material.

The minimum distance is often stipulated in national standards.

Under the following circumstances national standards may allow reduced distances:

— the power cable having a concentric neutral operates at low voltage and the telecommunication cable has an earthed armouring, or

— the cables are separated by concrete fillings or similar material.

If there is danger to staff doing manual excavation, high voltage power cables should be protected by covers of suitable material (brick, concrete, etc.).

3 Electromagnetic induction

In order to avoid inadmissibly high danger and interference to telecommunication cables from power cables the *Directives* must be observed. Such effects are especially to be expected when:

a) the power cable belongs to a network with a directly earthed neutral;

b) the individual phase conductors of the power line are run in separate cables (e.g. three-phase single-core cables); or

c) the currents in the power lines have a high harmonic content.

Danger and interference are not to be expected when:

— the power cable works under normal operational conditions, and in case of three-phase single-core cable the individual phase cables are properly arranged and transposed; or

— the length of the parallel running is relatively small (e.g. some hundred metres).

Proper arrangement and transposition of phase conductors of the power cable system are effective for reducing electromagnetic induction.

Other metallic conductors in the tunnel (e.g. pipe-lines, concrete reinforcements) have normally a reducing effect on the induced longitudinal voltages. The magnitude of this screening factor depends to a great extent on the arrangement of the various installations in the tunnel and on the construction of the tunnel and can, therefore, only be determined for each individual case.

4 Other dangers

The joint use of trenches and tunnels may increase the exposure of telecommunications staff to other dangers such as:

— striking power cables during excavation;

— access difficulties and isolation problems while working inside tunnels;

— explosions due to leakage from gas pipes if these are also present in jointly-used tunnels;

— foul air accumulations in tunnels.

Suitable safe working methods to overcome such dangers should be incorporated in the joint working agreement.

5 Practical limitations

The successful use of joint trenches and tunnels requires a disciplined cooperation by all parties concerned. The duties and responsibilities of each party should be precisely defined. Special measures may be necessary to overcome limitations of space underground and to facilitate subsequent maintenance of the cables, and such special measures need to be agreed before the joint construction work commences.

Recommendation K.20

RESISTIBILITY OF TELECOMMUNICATION SWITCHING EQUIPMENT TO OVERVOLTAGES AND OVERCURRENTS

(Malaga-Torremolinos, 1984)

1 General

This Recommendation seeks to establish fundamental testing methods and criteria for the resistibility of telecommunication switching equipment to overvoltages and overcurrents. It should be read in conjunction with the CCITT manual, *Protection of telecommunication lines and equipment against lightning discharges* and Recommendation K.11 which deals with the general economic and technical aspects of protection. The methods may be varied in the light of particular local circumstances and technical developments.

2 Scope

The Recommendation relates to telephone exchanges and similar telecommunication switching centres and is concerned mainly with test conditions to be applied to points intended for the connection of 2-wire subscriber lines. Ports carrying more complex circuits or more concentrated traffic (such as junctions or multi-channel circuits) may be tested either in accordance with this Recommendation or in accordance with other Recommendations such as K.15 and K.17, as considered appropriate.

The tests are type tests and, although they are applicable to a complete switching centre, it is recognized that they may be applied to individual items of equipment during development and design work. In making the tests, it is necessary to take account of any switching conditions, either in the unit under test or elsewhere, which may affect the results.

3 Overvoltages and overcurrent conditions

Aspects of overvoltage or overcurrent covered by this Recommendation are:

— surges due to lightning strokes on or near to the line plant; (equipment complying with this Recommendation may not necessarily resist severe direct lightning strokes);

— short-term induction of alternating voltages from adjacent power lines or railway systems, usually when these lines or systems develop faults;

— direct contacts between telecommunication lines and power lines, usually of a low voltage nature.

It is recognized that under some circumstances, problems may arise

if overvoltages or overcurrents occur simultaneously on a number of lines and produce large currents in common wiring or components. Such conditions are not covered by this Recommendation. The aspects of rise of earth potential is not covered but is being studied in CCITT.

4 Levels of resistibility

4.1 Only two levels of resistibility are covered: a lower level suitable for unexposed environments where overvoltages and overcurrents are low, and a higher level for more exposed environments. Account is taken of the fact that in the more exposed environments, protection may be fitted on the main distribution frame (MDF) or elsewhere outside the equipment.

4.2 Extreme conditions are not covered. In very sheltered environments, it may be possible for equipment of lower resistibility than specified herein to operate satisfactorily. On the other hand, equipment with even higher resistibility than specified may be needed for exceptionally exposed environments. Equally, other combinations of equipment resistibility and external protection are possible. For example, certain equipment may require protection even in unexposed environments and other equipment may operate satisfactorily in exposed environments without external protection.

Although only two categories of resistibility are described in this Recommendation, these cover a large proportion of present-day needs.

4.3 It is for Administrations to classify the environment of a particular switching centre , taking into account business policy, economic and technical considerations. Recommendation K.11 gives information to help in making this decision.

4.4 The test conditions and voltages of Table 1/K.20 reflect the conditions which are expected to occur on lines in unexposed environments.

4.5 The test conditions and voltages of Table 2/K.20 simulate the effects of an exposed environment on equipment protected by main distribution frame protectors and constitute additional requirements to ensure compatibility with external protection and proper functioning in the more severe environment. Higher voltages may well occur on the lines, but because the MDF protection operates, the effects on the equipment may not be more severe.

4.6 Equipment satisfying the requirements for an exposed environment may be used in either environment, but equipment satisfying only the requirements for an unexposed environment should be used only in an unexposed environment.

5 Exchange equipment boundary

The variations of different types of equipment make it necessary for each exchange to be seen as a ‘‘black-box’’ having three terminals, A, B and Earth. It is likely that some protective devices have already been provided in the equipment, either distributed on its line-cards , etc., or connected to its terminals. For the purpose of these tests, manufacturers are expected to define the boundaries of the ‘‘black-box’’ and any protective device which is included must be considered an immutable part of that exchange.

6 Test conditions

The following conditions apply to all the tests specified in § 8.

6.1 All tests are type tests.

6.2 The input terminals at which tests on the equipment are to be applied should be identified by the manufacturer and labelled A, B and Earth.

6.3 The equipment should be tested in any operating state of significant duration.

6.4 The equipment should be able to pass the tests in § 8 throughout the ranges of temperature and humidity of its intended use.

6.5 For tests in the ‘‘exposed’’ situation, it is current practice to protect subscribers’ lines at the MDF with some surge protectors such as gas-discharge tubes needed in most cases to handle high surge currents, and that the operation of these protectors exposes exchange switching equipment to other modified conditions, the characteristics of the external protectors to be used should be agreed between the equipment supplier and the Administration. Protectors having characteristics within the agreed range should be used where specified in Table 2/K.20. A new set of protectors may be used after the completion of each test sequence. Alternatively, some Administrations may choose to omit the external protectors but to modify the applied voltages and durations so that the conditions applied to the equipment are the same as could reasonably be expected to occur under the conditions of Table 2/K.20.

6.6 In all cases where a maximum voltage is specified, tests should also be made at lower voltages if this is necessary to confirm that the

equipment will resist any voltage up to the maximum value specified.

6.7 Each test should be applied the number of times indicated in the relevant table. The time interval between applications should be 1 minute and, in the case of pulse tests, the polarity should be reversed between consecutive pulses.

6.8 Power induction and power contact tests should be made at the frequencies of the a.c. mains or electric railways used in the country of application.

7 Permitted malfunction or damage

Two levels of malfunction or damage are recognized:

Criterion A — Equipment shall withstand the test without damage or other disturbance (such as corruption of software or misoperation of fault-protection facilities) and shall operate properly within the specified limits after the test. (It is not required to operate correctly while the test condition is present.) If specifically permitted by the Administration, the test may cause the operation of fuses or other devices which have to be replaced or reset before normal operation is restored.

Criterion B — A fire hazard should not arise in the equipment as a result of the tests. Any damage or permanent malfunction occurring should be confined to a small number of external line interface circuits.

The conditions likely to give rise to Criterion B are considered to be so rare that complete protection against them is not economical.

8 Tests

8.1 *General*

The test circuits used for the three overvoltage or overcurrent situations are as follows:

— Figure 1/K.20: lightning surges ;

— Figure 2/K.20: power induction ;

— Figure 3/K.20: power contacts

Note — Certain considerations which justify the test proposals are stated in Annex A to this Recommendation. The response of equipment to lightning surges may be modified by the input impedance of the equipment. To explain this effect, Annex A includes an example in which, for clarity, values are assigned to the input impedance so that instantaneous levels of voltage at different points in the circuit may be compared. These values are included for illustration only and do not form any part of this Recommendation.

8.2 *Unexposed environment*

Equipment for use without external protection in unexposed environments should be tested according to Table 1/K.20.

8.3 *Exposed environment*

Equipment for use in exposed environments should pass the tests described in Table 1/K.20 and also those in Table 2/K.20.

H.T. [T1.20]

TABLE 1/K.20

Test conditions and voltages for unexposed environments

lw(12p) | lw(30p) | lw(30p) | lw(48p) | lw(48p) | lw(30p) | lw(30p) .

Tableau 1/K.20 [T1.20], p.

H.T. [T2.20]

TABLE 2/K.20

Test conditions and voltages for exposed environments

lw(12p) | lw(30p) | lw(30p) | lw(42p) | lw(36p) | lw(24p) | lw(30p) | lw(24p) .

Tableau 2/K.20 [T2.20], p.

Figure 1/K.20, p.

Figure 2/K.20, p.

Figure 3/K.20, p.

ANNEX A

(to Recommendation K.20)

Explanations which illustrate test conditions

A.1 *Lightning surges*

A.1.1 *Operation of simulation circuit*

Figure A-1/K.20 shows the test generator of Figure 1/K.20 connected to an example of an exchange circuit with primary protection provided at the MDF and secondary protection in the exchange equipment itself. Apart from the test generator of Figure 1/K.20, all the circuit layout and component values have been chosen purely for explanatory purposes and are not put forward as some recommended practice.

When the charging voltage, U_c, is progressively raised, the voltages and currents which occur at various points in the circuit of Figure A-1/K.20 are shown on the graph in Figure A-2/K.20.

For U_c = 0-300 V, the current flows only through the 100 Ω resistor in the equipment.

At U_c = 300 V, the secondary protection operates and the current I_T rises more rapidly.

At U_c = 2385 V, the voltage U across the primary protection reaches U_s=700 V in the case illustrated, and I_E reaches its maximum value of 3 A.

The primary protection operates when U_c= 2385 V and the total current thereafter rises still more rapidly, reaching 100 A when U_c = 4 kV. The voltage U however drops to a low value and the current I_E flowing into the equipment falls to a very low value and becomes practically independent of U_c.

Figure A-1/K.20, p.280

Figure A-2/K.20, p.281

A.1.2 *Effect of protective devices*

Operation of the primary protection when $U = U_s$ therefore has two effects:

— it limits the maximum voltage applied to the equipment and hence, depending on the internal impedance of the equipment, the maximum current which the equipment must withstand;

— it produces a very rapid change in U and I which, by inductive or capacitive effects can reach sensitive parts of the exchange switching equipment not apparently exposed to line voltages.

For these reasons it is important that the Administration and equipment suppliers should agree on the primary protection which should be used and for the equipment user to provide or simulate this protection when tests are made. The tolerances allowed for such protection components should be taken into account when tests are made.

A.2 *Power induction*

Induced voltages are likely to occur more on long lines, and in the general case where subscribers' lines do not provide a low resistance earth, induced voltages may be considered to have a high source impedance consisting of a 600 Ω wire resistance in series with 1 µF line to earth capacitance as shown in Figure A-3/K.20. Tests 3(a) and 3(b) of Table 2/K.20 represent typical requirements for long and short lines respectively but they do not necessarily provide for limiting conditions. The gas discharge tube shown in Figure A-3/K.20 only exists on exposed lines. Such tubes are represented by S_2 in Figure 2/K.20 and the telephone is represented by S_1.

CCITT Directives admit induced voltages up to 430 V from normal power lines and 650 V from high-security lines, but most Administrations expect voltages to be below 300 V except on the lines in exposed environments.

Figure A-3/K.20, p.282

A.3 *Power contacts*

Direct contact with electrical mains power can occur through network line or cable faults, faulty or unapproved subscriber equipment or other causes. The contact may not cause the operation of a power system circuit-breaker. A.c. currents resulting from a direct contact may make effective protection both difficult and expensive. As such events are rare, equipment is not required to withstand overvoltages or overcurrents arising from direct contacts but may fail in an acceptable manner.

Two particular dangers to equipment may arise:

— a contact near to an exchange where the combined impedance of the cable circuit and exchange termination is low and a high current flow occurs. This condition is simulated by the test in Figure A-4/K.20 by applying 220 V through an impedance of 10 Ω;

— a contact at the maximum distance from an exchange where the combined impedance of the cable circuit and exchange termination is high and a small but harmful current flows continuously. This condition is simulated by the test in Figure A-4/K.20 by applying 220 V through an impedance of 600 Ω.

Figure A-4/K.20, p.283

Recommendation K.21

RESISTIBILITY OF SUBSCRIBERS' TERMINALS TO OVERVOLTAGES AND OVERCURRENTS

(Melbourne, 1988)

Introduction

This Recommendation has been produced by Study Group V to meet the urgent requirements of Administrations and manufacturers who are using or designing subscriber's equipment. The attention of the reader is drawn to the following subjects which CCITT is studying further:

— rise of earth potential;

— electrical fast transients;

— operational tests for barriers between mains ports and telecommunication ports;

— high frequency mains-voltage surges;

— short duration interruptions of mains voltages.

When these studies have been completed, this Recommendation may be expanded.

1 Purpose of the Recommendation

When modern telecommunications equipment is connected to local subscribers' lines, the equipment may be damaged as a result of overvoltages or overcurrents which occur on these lines under occasional conditions. The probability and magnitude of these conditions vary due to many factors, e.g. geography, climate, construction methods, shielding effects. Overvoltage or overcurrent surges arising from electrostatic discharges or transient surges which occur on mains-voltage power supplies may also damage equipment or cause its misoperation. This Recommendation seeks to establish fundamental testing methods which may be varied in detail to suit particular local circumstances and which help to predict the likelihood of survival when the equipment is exposed to these overvoltages or overcurrents.

In its present form, the Recommendation describes tests that should be applied to equipment which is metallically connected directly to balanced pairs. Further studies relating to equipment connected to coaxial and optical fibre cables are being made.

The Recommendation assumes that line protectors are fitted externally to the equipment in exposed areas. Administrations individually will decide their policies for protection. The guidance of Recommendation K.11 should be followed when making this judgement and should take account of the routing of lines to the equipment, in addition to its location.

2 Scope

This Recommendation deals principally with desk-borne equipment. Recommendation K.20 deals with switching equipment powered by central-battery. For the more complex subscriber equipment, Administrations should use either Recommendation K.20 or K.21 as appropriate.

The Recommendation relates to type tests only. Recognizing the difficulty in testing a complex item of subscribers' equipment, the Recommendation concentrates on a series of tests made principally at the telecommunication line and mains input terminals. The tests should be applied at any chosen stage during the normal use of the equipment.

As the equipment may be used in either an exposed or unexposed environment, tests are made with and without line protectors fitted.

The tests for lightning surges assume that an electrical connection between the power system earth terminal and the telecommunications equipment earth can be effected. A study of special test requirements for situations where this is not possible is being made.

The tests for power induction apply only to longitudinal effects and a further study is being made of test requirements for transverse surges.

Some aspects of rise of earth potential, such as may arise from a power line system fault, are not at present covered but are being studied.

Electrical fast transient requirements are not yet included and a study is being made of test requirements for both the telecommunication and mains power lines.

The Recommendation deals primarily with reliability of equipment and although it may provide some level of safety, it is not sufficient by itself to fully protect the user. National standards for electrical safety should be followed in each country where the equipment is used. Furthermore, this Recommendation is not intended to establish whether equipment could produce harmful effects to the network when connected. Interference from low frequency induced voltages or radio frequency interference to the operation of the equipment is not included.

3 Overvoltage and overcurrent conditions

Aspects of overvoltage or overcurrent covered by this Recommendation are:

— surges due to direct or indirect lightning strokes on or near the line plant;

— short-term induction of 50B/F60 Hz voltages from adjacent power lines or railway systems, usually when these lines or systems develop faults;

— direct contacts between telecommunications lines and power lines, usually of a low voltage nature;

— electrostatic discharges generated by users touching the equipment or adjacent plant;

— transient surges on mains-voltage power supplies to the equipment.

4 Equipment boundary

Variations in equipment make it necessary for each unit to be seen as a ‘‘black box’’ having three or more terminals, A, B, etc. and E (earth). Some protective devices may have already been provided within the equipment, e.g. distributed on cards, or connected to internal terminals. For the purposes of these tests, manufacturers are expected to define the boundaries of the ‘‘black box’’ and any protective device which is thereby included must be considered as an immutable part of the equipment. Where any auxillary telecommunications lead is provided, e.g. to an extension, or as a signalling earth, these wires should be seen to extend the number of terminals to be tested, e.g. A, B, C, D, etc. and E (earth).

5 Test conditions

The following general conditions apply to all the tests specified in §§ 7, 8 and 9 except where otherwise stated.

1) All tests are type tests.

2) The input terminals at which tests on the equipment are to be applied should be identified by the manufacturer and labelled A, B, C, D, etc. and Earth.

3) For the tests specified in §§ 7 and 9 only, the equipment should be enclosed in a foil shroud over those parts likely to have a human contact during use, and the foil connected to the E terminal.

4) The equipment should be tested in each operating mode of significant duration.

5) The equipment should pass the tests listed in §§ 7 and 9 throughout the ranges of temperature and humidity of its intended use.

6) Some of the tests in Table 1/K.21 require the addition of agreed primary protection. It is current practice to protect exposed subscribers’ lines with some surge protectors such as gas-discharge tubes. Recognizing that some such device is likely to be needed in most cases to handle high surge currents, and that the operation of these protectors exposes subscribers’ equipment to other modified conditions, the characteristics of the external protectors to be used should be agreed between the equipment supplier and the Administration. Administrations applying the tests included in this Recommendation are free to select such protectors with any characteristics within the range acceptable for these nominated devices, when carrying out tests with external protection fitted.

Protectors having characteristics within the agreed range should be used where specified in Table 1/K.21. A new set of protectors may be used after the completion of each test sequence. Alternatively, some Administrations may choose to omit the external protectors and to modify the applied voltages and durations, so that the conditions applied to the equipment are the same as could reasonably be expected to occur under the conditions of Table 1/K.21.

7) In all cases where a maximum voltage is specified, tests should also be made at lower voltages if this is necessary to confirm that the equipment will resist any voltage up to the maximum value specified.

8) Each test should be applied the number of times indicated in Table 1/K.21. The time interval between applications should be one minute and, in the case of pulse tests, the polarity should be reversed between consecutive pulses.

9) Power induction and power contact tests should be made at the frequency of the a.c. mains or electric railway used in the country of application.

6 Permitted malfunction or damage

Two levels of malfunction or damage are recognized:

— *Criterion A* — Equipment shall withstand the test without damage or other disturbance, e.g. corruption of software or misoperation of fault-protection facilities and shall operate properly within the specified limits after the test. It is not required to operate correctly while the test condition is present.

If specifically permitted by the Administration, the test may cause the operation of fuses or other devices which have to be replaced or reset before normal operation is restored.

— *Criterion B* — A fire hazard should not arise in the equipment as a result of the tests. Any damage or permanent malfunction occuring should be confined to a small number of external line interface circuits.

The conditions likely to give rise to criterion B are considered to be so rare that complete protection against them is not economical.

7 Tests related to lightning surges, power induction and contacts

The test circuits used for the three overvoltage or overcurrent conditions are as follows:

— Figure 1/K.21: lightning surges;

— Figure 2/K.21: power induction;

— Figure 3/K.21: power contacts.

The equipment should be tested according to Table 1/K.21.

8 Tests related to electrostatic discharges

The requirements of IEC publication 801-2 [1] should be followed. The equipment should meet criterion A of this Recommendation when tested to both severity levels 2 and 4 of IEC 801-2. These two severity levels have been chosen because at severity level 2, the rise time is much faster than that at severity level 4. This fast rise time may cause coupling into sensitive circuits to take place and will require an assessment for misoperation due to software corruption, rather than just for energy dissipation.

However, when deemed appropriate by an Administration, alternative severity levels of testing may be used. In addition, an Administration may choose to relax the conditions of criterion A to a limited extent.

9 Tests related to mains-powered equipment

The following tests are made on mains-powered equipment to ensure that the equipment can adequately resist high voltage surges which may arise on power conductors from lightning or other causes, such as load switching.

The equipment under test should be tested with normal operating power applied and with the telecommunication line access at the equipment terminated in such a manner as to simulate the conditions in each state of operation of significant duration.

Figure 1/K.21, p.

Figure 2/K.21, p.

Figure 3/K.21, p.

H.T. [T1.21]

TABLE 1/K.21

No. Maximum test voltage and duration } Added protection [see 6) of § 5] } Acceptance criteria (see § 6) }	Test Number of tests {	Terminal connections {	Test circuit	{			
1	Lightning surge simulation	{		None *U = 4 kV (Note 3)*	Criterion A *10*	*Agreed primary protection*	*Criterion A*
2 U | (m a x) = 300 V rms for 200 ms (Note 4) } 3 Figure 3/K.21 Tests made with S in each position (Note 6) } U | (m a x) = 230 V rms for 15 min (See Note 4) }	*Power induction 5 Power contact { 1 For each position of S*	*T 1 and A T 2 and B T 1 and A T 2 and B None T 1 and A T 2 and B None*	*Figure 1/K.21 Figure 2/K.21 S unoperated Criterion A Figure 2/K.21 S operated { Criterion B*	*U = 1.5 kV (Note 2) U = 4 kV (Note 3) { (Note 5)*	*10 10 1*	*None Agreed primary protection Agreed primary protection*	*Criterion A Criterion A Criterion B*

Note 1 — An earthed connection may prevent the establishment of normal operation conditions when the test is made. In these cases, alternative testing procedures should be followed to meet the requirements of this test (e.g. a low voltage spark-gap or other variation in the earth connection should be used).

Note 2 — Administrations may choose other values of *U*
| (m a x) to suit local circumstances, e.g. to avoid the use of protectors or to align with the impulse spark-over voltage of protectors that are normally used.

Note 3 — Administrations may vary *U*
| (m a x) to meet their local requirements.

Note 4 — Administrations may specify lower values of *U*
| (m a x) and may vary the duration of the test to meet their local requirements (e.g. local mains voltages).

Note 5 — Voltages and durations should be in accordance with CCITT directives or such other limits as Administrations.

Note 6 — Fuses, fuse cables, etc., may be left in circuit during these tests. The current conducted by wiring shall not constitute a fire hazard within the premises where the equipment is located.

Tableau 1/K.21 [T1.21], p.

Equipment not complying with a) below should meet criterion A of this Recommendation when tested with surge tests applied between phase, neutral and protective earth terminals of the equipment in accordance with b) below.

a) *Insulation coordination*

IEC publication 664 [2] describes overvoltage categories for mains-powered equipment, including telecommunication equipment, in respect of overvoltages arising in the supply network. Most subscribers' equipment is expected to be installed in overvoltage category 11 in which the maximum surge voltage arriving at its mains terminals is 2.5 kV peak. Given this and certain other assumptions about atmospheric pollution (e.g. dust) and the quality of insulation, IEC 664 gives guidance to IEC standards committees on coordinated creepage distances and clearances that can be expected to give adequate performance during the lifetime of the equipment.

The guidance in IEC 664 has been adopted in IEC publication 950 [3]. Subject to cases mentioned in c) below, telecommunication equipment that employs insulation spacings that are dimensioned and tested in accordance with IEC 950 need not to be subjected to further tests under this Recommendation.

b) *No insulation coordination*

Where reliance is not placed on insulation coordination, the equipment shall be subjected to tests along the lines indicated in references [3] to [5].

c) *Exceptional overvoltages*

In cases where electrical disturbances may be of exceptional amplitude or simply greater than the values adopted for the tests, it is recommended that additional protective measures external to the terminal equipment be used, e.g.:

— power transformers with high dielectric strength (or the order of 10 kV) in relation to the mains leads;

— overvoltage limiting devices such as lightning arrestors, air gaps, non-linear resistances, etc.;

— combinations of the above.

Note 1 — For situation a), the experience of one country has shown that a Rec. K.17 generator may be substituted, i.e. with a waveshape 10/700 µs and an internal impedance of 40 ohms. A test voltage of $V_{c(\max)}$ = 2.5 kV assured a satisfactory performance of equipment operated at a load level interface of low-voltage distribution systems with a nominal voltage of 230/400 V.

Note 2 — Attention is drawn to matters of safety which relate to electrical barriers between the mains power and telecommunication line terminals. These are normally subject to national regulations which have to be followed in each country.

References

1] IEC publication 801-2, *Electromagnetic compatibility for industrial-process measurement and control equipment* , *Part 2: Electrostatic discharge requirements* , Geneva, 1984.

[2] IEC publication 664 *Insulation co-ordination within low-voltage systems including clearances and creepage distances for equipment* , Geneva, 1980.

[3] IEC publication 950 *Safety of information technology equipment including electrical business equipment* , Geneva, 1986.

[4] ANSI/IEEE Standard C 62.41, *IEEE guide for surge voltages in low-voltage AC power circuits* , New York, 1980.

[5] CENELEC ENV 41003 *Particular requirements for information technology equipment when connected to a telecommunication network* , Brussels, 1988.

Recommendation K.22

OVERVOLTAGE RESISTIBILITY OF EQUIPMENT

CONNECTED TO AN ISDN T/S BUS

(Melbourne, 1988)

1 General

This Recommendation seeks to establish fundamental testing methods and criteria for the resistibility of telecommunication equipment connected to an internal ISDN T/S bus.

Recommendation K.21 should be followed when assessing the resistibility of equipment to be connected directly to a telecommunication network.

2 Scope

The Recommendation relates to any terminal equipment which is intended to be connected to the 4-wire T/S bus of an ISDN installation. It presumes that suitable isolation is provided between the telecommunication network and the T/S bus at the network termination. It is also assumed that the S-bus has no connection to earth, e.g. no earth-connected voltage-limiting devices with non-linear characteristics can be used. In cases where these assumptions cannot be made, Recommendation K.21 should be followed.

3 Overvoltage and overcurrent conditions

Aspects of overvoltage or overcurrent covered by this Recommendation are:

— surges due to lightning strokes on telecommunication lines or to the building housing the equipment;

— electrostatic discharges generated by users touching the equipment or adjacent plant;

— lightning transient surges on mains-voltage power supplies to the equipment.

4 Equipment boundary

Variations in equipment make it necessary for each unit to be seen as a ‘‘black box’’ having three or more terminals, A, B, | | | , etc. Some protective devices may have already been provided within the equipment, e.g. distributed on cards, or connected to internal terminals. For the purposes of these tests, manufacturers are expected to define the boundaries of the ‘‘black box’’ and any protective device which is thereby included must be considered as an immutable part of the equipment.

5 Test conditions

The following general conditions apply:

1) All tests are type tests.

2) The input terminals at which tests on the equipment are to be applied should be identified by the manufacturer and labelled A, B, etc.

3) For the tests specified in §§ 7 and 9 only, the equipment should be enclosed in a foil shroud over those parts likely to have a human contact during use, and the foil connected to the earth terminal (if it is provided).

4) The equipment should be tested in each operating mode of significant duration.

5) The equipment should pass tests under §§ 7 and 9 through the ranges of temperature and humidity of its intended use.

6) In all cases where a maximum voltage is specified, tests shall also be made at lower voltages if it is necessary to confirm that the equipment will resist any voltage up to the maximum specified.

6 Test compliance

Equipment shall withstand all tests without damage or other disturbance, e.g. corruption of software, misoperation of fault-protection facilities, and shall operate properly within specified limits after the tests. It is not required to operate correctly while the test condition is present.

If specifically permitted by the Administration, the tests may cause the operation of fuses or other devices which have to be replaced or reset before normal operation is restored.

7 Surge tests

7.1 *Test circuits*

Three alternative test circuits may be used:

— a surge generator of 1.2/50 µs open-circuit voltage waveshape and 8/20 µs short-circuit current waveshape;

— a surge generator of 2/10 µs open-circuit voltage waveshape and the same short-circuit current waveshape;

— a surge generator of 1.2/50 µs open-circuit voltage waveshape and a corresponding short-circuit current waveshape. Figure 1/K.22 illustrates a typical test circuit.

The short-circuit current provided by the surge generator shall be approximately 100 A.

Figure 1/K.22, p.

7.2 *Tests*

The open-circuit voltage of the surge generator should be 1 kV. The surge generator should be connected to the equipment under test through the circuit of Figure 2/K.22. Ten tests should be made with alternating positive and negative polarities.

FIGURE 2/K.22, p.

8 Tests for electrostatic discharges

The equipment should meet the requirements of IEC publication 801-2 [1] when tested to both severity levels 2 and 4. The two severity levels have been chosen to ensure the equipment is tested with both fast rise times and high test voltages.

9 Tests related to mains-powered equipment

The following tests are made on mains-powered equipment to ensure that the equipment can adequately resist high voltage surges which may arise on power conductors from lightning or other causes, such as load switching.

The equipment under test should be tested with normal operating power applied and with the telecommunication line access at the equipment terminated in such a manner as to simulate the conditions in each state of operation of significant duration.

Equipment not complying with a) below should meet the requirements of § 6 of this Recommendation when tested with surge tests applied between phase, neutral and protective earth terminals of the equipment in accordance with b) below.

a) *Insulation coordination*

IEC publication 664 [2] describes overvoltage categories for mains-powered equipment, including telecommunication equipment, in respect of overvoltages arising in the supply network. Most subscribers' equipment is expected to be installed in overvoltage category 11 in which the maximum surge voltage arriving at its mains terminals is 2.5 kV peak. Given this and certain other assumptions about atmospheric pollution (e.g. dust) and the quality of insulation, IEC 664 gives guidance to IEC standards committees on coordinated creepage distances and clearances that can be expected to give adequate performance during the lifetime of the equipment.

The guidance in IEC 664 has been adopted in IEC publication 950 [3]. Subject to cases mentioned in c) below, telecommunication equipment that employs insulation spacings that are dimensioned and tested in accordance with IEC 950 need not be subjected to further tests under this Recommendation.

b) *No insulation coordination*

Where reliance is not placed on insulation coordination, the equipment shall be subjected to tests along the lines indicated in [3] to [5].

c) *Exceptional voltages*

In cases where electrical disturbances may be of exceptional amplitude or simply greater than the values adopted for the tests, it is recommended that additional protective measures external to the terminal equipment be used, e.g.:

— power transformers with a high dielectric strength (of the order of 10 kV) in relation to the mains leads;

— overvoltage limiting devices such as lightning arrestors, air gaps, nonlinear resistances, etc.;

— combinations of the above.

Note 1 — For situation a), the experience of one country has shown that a Rec. K.17 generator may be substituted, i.e. with a waveshape 10/700 μs and an internal impedance of 40 ohms. A test voltage of $V_{c(\max)}$ = 2.5 kV assured a satisfactory performance of equipment operated at a load level interface of low-voltage distribution systems with a nominal voltage of 230/400 V.

Note 2 — Attention is drawn to matters of safety which relate to electrical barriers between the mains power and telecommunication line terminals. These are normally subject to national regulations which have to be followed in each country.

Note 3 — The attention of the reader is drawn to the following subjects which CCITT is studying further:

— rise of earth potential;

— electrical fast transients;

— operational tests for barriers between mains ports and telecommunication ports;

— high frequency mains-voltage surges;

— short duration interruptions of mains voltages.

When these studies have been completed, this Recommendation may be expanded.

References

[1] IEC publication 801-2 *Electromagnetic compatibility for industrial-process measurement and control equipment, Part 2 | Electric discharge requirements* , Geneva, 1984.

[2] IEC publication 664 *Insulation coordination within low-voltage systems including clearances and creepage distances for equipment* , Geneva, 1980.

[3] IEC publication 950 *Safety of information technology equipment including electrical business equipment* , Geneva, 1986.

[4] ANSI/IEEE Standard C 62.41 *IEEE guide for surge voltages in low-voltage AC power circuits* , New York, 1980.

[5] CENELEC ENV 41003 *Particular requirements for information technology equipment when connected to a telecommunications network* , Brussels, 1988.

Recommendation K.23

TYPES OF INDUCED NOISE AND DESCRIPTION OF NOISE VOLTAGE PARAMETERS FOR ISDN BASIC USER NETWORKS

(Melbourne, 1988)

1 Purpose of this Recommendation

This Recommendation has been produced by Study Group V to meet the urgent requirements of Administrations, manufacturers, and users who should evaluate equipment for its immunity to induced noise in order to design and use the ISDN.

The Recommendation identifies the types of induced noise that can cause degradation of transmission quality and malfunction of the equipment, and the noise voltage parameters that should be evaluated.

2 Scope

This Recommendation covers the degradation of equipment performance due to induced noise voltage on metallic pair cables (including residential inside wire), which is caused by an inducing source external to the cable or by another telecommunication system. However, this Recommendation does not cover interference caused by transmission characteristics of cables (for example, cross talk characteristics).

The Recommendation considers the characteristics of induced noise voltages at metallic-pair ISDN interfaces at subscriber’s premises. Interface locations covered by this Recommendation are the S and T interfaces (see Recommendation I.430) as well as the 2-wire interface of the NT1.

The communication line constituting the S/T bus may be confined to a building or connect two separate buildings. The connecting telecommunications line may be either aerial or below-ground.

3 Types of induced noise affecting the ISDN

3.1 *Mode of voltage*

Two voltage modes should be considered: longitudinal voltage and transverse voltage. Figure 1/K.23 illustrates the definition of longitudinal voltage induced in telecommunication lines and the transverse voltage

When longitudinal voltage is present at equipment interfaces, it may cause malfunction of the equipment. The transverse voltage is induced by conversion from the longitudinal voltage because of transmission line and input terminal equipment impedance unbalance, and by direct coupling with the inducing source. It may cause a degradation of transmission quality. Therefore, both the longitudinal voltage and the transverse voltage should be considered (Figure 2/K.23).

Figure 1/K.23, p.

Figure 2/K.23, p.

3.2 *Waveshape of induced noise voltage*

From a waveshape viewpoint, induced noise voltage can be categorized into continuous noise voltage (such as a broadcast wave) and transient noise voltage (such as a switching noise voltage).

The continuous noise waveshape can be reproduced from the components of the frequency spectrum. Continuous noise causes a degradation of the signal-to-noise ratio, which may cause an increase in the error rate.

On the other hand, the transient noise waveshape is composed of spark type waves. As the pulse width of one transient wave is much less than the duration time between two transient waves, each transient wave can be treated as an independent wave. Therefore, a knowledge of the total time of transient noise exceeding the decision voltage is important to the evaluation of digital transmission quality. To evaluate equipment malfunction, the above features of the noise waveshape should be considered.

3.3 *Equipment performance categories*

The induced noise described above may have a number of different functional effects on the performance of equipment and transmission quality. These fall into the following categories:

1) no loss of performance or function;

2) temporary loss of function or performance which is self-recoverable;

3) temporary loss of function or performance which requires operation intervention or system reset;

4) loss of function which is not recoverable due to damage of equipment (components), or due to the continuous nature of the interference.

Table 1/K.23 lists various noise sources that cause induced voltage on transmission lines. It also lists the categories 1) to 4) above of degradation of equipment performance and transmission quality, and the interfaces to be considered for each noise source.

H.T. [T1.23]

TABLE 1/K.23

{

Categorization of induced noise source, waveshape to be evaluated, interference to be evaluated and line interfaces involved

}

{	Wave shape to be evaluated Interface to be considered Continuous noise	{ Transient noise	1	2	3	4	2-wire NT	S and T

○1 Radio broadcast	X	X	X	X	X					
○2 Mobil transceiver	X	X	X	X	X	X				
External induced noise	{	X X	X X	X X	X X	X X	X X	X X	○4 Electric railway ○5 Lightning	X

{
○
6
Automotive engine ignition
}
	X	X	X	X	X	X				

{
○
7
Electrostatic discharge
}
	X	X	X	X	X	(Note 2)	(Note 2)			

	{	X X	X X	X (Note 3) X (Note 3)	X (Note 3) X (Note 3)	○9 Switching	X	X		
{	{ X X X	X X	X X	X X	X X	X	{			

Tableau 1/K.23 [T1.23] (a l'italienne), p.18

4 Induced noise voltage parameters that should be evaluated

Evaluation of transmission quality and malfunction of the equipment using raw data from various induced noise voltage waves is too inefficient. Therefore, it is useful to describe waveshapes using several parameters, which are found by analyzing waveshape features, and to establish a standardized measurement method and a standardized test procedure. This will enable an efficient evaluation of the effect which induced noise voltage has on the digital transmission quality and the malfunction of equipment.

Continuous noise voltage should be evaluated using the amplitudes of the frequency spectrum as a basic parameter since from these amplitudes the waveshapes can be reproduced. Transient noise voltage should be evaluated using amplitude probability distributions, and frequency spectrum as well as waveshape parameters in the time domain (for example, peak value, periodic time, decay time, duration time of burst, etc.). These basic parameters can be used to design a transient noise simulator.

Table 2/K.23 lists some induced noise voltage parameters that should be evaluated.

Tableau 2/K.23, p.

Recommendation K.24

METHOD FOR MEASURING RADIO-FREQUENCY INDUCED NOISE ON TELECOMMUNICATIONS PAIRS

(Melbourne, 1988)

1 Purpose of this Recommendation

This Recommendation is intended to standardize the method for measuring radio-frequency induced noise that may cause degradation of equipment performance and transmission quality. Standardization of the method for measuring induced noise makes possible the international standardization of the quality of the telecommunication system.

2 Scope

This Recommendation considers measurement methods for radio-frequency induced noise at any telecommunication pair. Locations for measurement are both the cable cntry into a building and the interface point of a terminal equipment.

The frequency range to be considered is 10 kHz to 30 MHz.

Note — Above 30 MHz, the technical problems of making measurements have not been solved and are therefore still under study.

3 Circuits for measuring radio-frequency induced noise voltage

1) *Measured mode of induced noise voltage*

Both transverse and longitudinal voltages should be measured.

2) *Measured condition of telecommunication line*

Measurements should be made with all telecommunications equipment disconnected at measuring end and with a measurement termination network.

i) *Termination network for measurements*

Measurements should be made at both the cable entry point into the subscribers premises and at the terminal equipment point. In the measurement, a T network shown in Figure 1/K.24 should be used. The longitudinal conversion loss of the T network should be at least 10 dB higher than the value of the LCL for the cable type to be measured (e.g. 60 dB cable requires 70 dB measurement termination network).

Note — Values of R_x and R_y are under consideration. Administrations and RPOAs are requested to make measurements at both sets of values indicated in Figure 1/K.24.

ii) *Reference earthing point*

Either of two reference earthing points may be used. In order of preference they are: 1) the screen of the cable, or 2) the primary protection ground terminal, protective earth, or nearby grounded metal work. Since it affects the result, the reference earthing point used for a measurement should be stated.

Note — For transverse measurements, a connection to a reference point may not be required, but care must be taken with the capacitance of the measurement equipment to ground. This may be done by using battery powered measuring equipment. An isolating transformer for mains-powered equipment, or a balun termination network, must be used when measuring metallic transverse voltage.

iii) *Termination network to use at the central office*

On inside house wire (such as the S/T interface line of ISDN) it is important to terminate the far end of the cable. However, when measuring at the entry point of the local network into the customer's premises (such as the 2-wire interface to NT1 of ISDN), it is not important to have a termination at the far end if the cable length exceeds 1 km. Less than 1 km, it may still be possible to make measurements without terminating the far end, depending on the frequency of the interfering signal and the make-up of the local network.

3) *Detector type*

The detector shall have fundamental characteristics as defined in Section 1 of CISPR specification for radio interference measuring apparatus and measurement method, CISPR publication No. 16, 1987.

4) *Bandwidth of measurement*

The bandwidth of measurement shall have fundamental characteristics as defined in Section 1 of CISPR specification for radio interference measuring apparatus and measurement method, CISPR publication No. 16, 1987.

Improvements in narrowing the bandwidth and the standardization of appropriate measuring equipment needs further study in cooperation with CISPR (International Special Committee on Radio Interference.).

5) *Electric field immunity of measurement equipment*

The test equipment should have an overall immunity to electromagnetic fields in accordance with CISPR publication 16. Adequate accuracy should be provided for extending the use of the equipment to locations with field strengths above 3 V/m to 10 V/m.

Figure 1/K.24, p.,

Recommendation K.25

LIGHTNING PROTECTION OF OPTICAL FIBRE CABLES

(Mlebourne, 1988)

1 Introduction

Communications using optical fibres are commonly considered to be immune from damage through surge currents, e.g. lightning. Not all optical fibre cables are, however, completely non-metallic. Components which provide tensile strength during installation, a moisture barrier, rodent protection or communication facilities during repairs may have metal parts. Lightning may strike these components and damage may be caused to the cable.

This damage may be minimized if adequate insulation exists to separate metallic components and if the cable is designed to withstand thermal and mechanical effects at the location of the strike. Adequate dielectric strength between metallic components may prevent repeated arcing taking place between components.

General information regarding the protection of telecommunication lines against lightning given in the manual *The protection of telecommunication lines and equipment against lightning discharges* [1] can be used for both aerial and buried plants with optical fibre cables containing metallic components.

This Recommendation gives interim advice as follows:

— guidance in the use of the manual [1] to evaluate the need to protect optical fibre cables (§ 2) and in selecting the protective measures to minimize damage due to lightning (§ 3);

— to give test methods to evaluate the resistibility of optical fibre cables (§ 3.4).

Future work on this Recommendation is described in § 5.

2 Need for protection

The need for lightning protection of an optical fibre cable depends on the annual frequency of fibre damage N_d and on its tolerable number N_t.

The annual damage rate can be estimated by using the manual [1], Chapter 7 *Frequency of breakdowns in telecommunication systems as a result of lightning discharges*. See also § 5 below.

The maximum lightning current which does not cause faults in the cable is the admissible current indicated in the formulae of this chapter and it refers to secondary damage, i.e. dielectric breakdown in the cable.

The admissible current related to the primary damage, i.e. loss of transmission or lowered resistance to moisture penetration of the cable, can be evaluated by means of the test methods described in § 3.4 below.

If the annual damage rate N_d is higher than the tolerable number of faults N_t, protection measures are necessary to reduce N_d and to minimize the risk of such damage.

Each Administration can define its tolerable number of faults.

3 Protective measures

Protective devices and practices for telecommunications networks are indicated in Chapters 5 and 6 of the manual [1].

For optical fibre cables, the following protective measures are usually considered:

3.1 *Correct connection of metallic moisture barriers*

The moisture barrier of an optical fibre cable should be continuous, i.e. it should be connected across all splices, regenerators etc., along the length of the cable. The moisture barrier should be connected to earth, either directly or through lightning arrestors, at the termination at each end of the cable length.

3.2 *Use of shield wires above the cable*

It may be important to protect the plastic sheath of the moisture barrier against perforation due to lightning discharges. Such a perforation may occur if the potential of the soil relative to remote earth as a result of a lightning strike exceeds the breakdown voltage of the polyethylene sheath of the moisture barrier.

The installation of a shield wire above the optical fibre cable will reduce the likelihood of the polyethylene sheath of the moisture barrier being perforated.

The efficiency of shield wires can be very considerable and can be derived from Chapter 7 of the manual [1].

3.3 *Use of metal-free cables*

This type of cable may be suitable for use in areas exposed to lightning or where severe power induction is experienced. While damage due to these causes may be minimized or prevented, for buried cables the lowered resistance of the cables to moisture penetration and the difficulty of locating them during subsequent maintenance activities should be considered.

3.4 *Use of cables which have metal components but have adequate resistibility to a level of lightning surge currents*

Cables of this type may carry lightning currents during storms, but the passage of these currents is not expected to cause dielectric breakdown or transmission impairment. Two tests have been devised for these cables: one test to establish that adequate dielectric strength exists for general cases and the other to determine threshold values of surge current resistivity for cable selection. The two tests are as follows:

— *Test for dielectric strength*

The metallic components which are electrically insulated from each other should be considered in pairs. Any pair should be tested where a discharge across the pair might intercept either an optical fibre or a non-metallic moisture barrier. If a cable has a metallic moisture barrier, tests should be made additionally between this barrier and each metallic component insulated from it. Either a.c. or d.c. may be used to carry out these dielectric strength tests. For a.c. tests, 10 kV r.m.s. at a frequency of 50 or 60 Hz shall be applied to the pair of metallic components for five seconds. For d.c. tests, 20 kV shall be applied to the pair of metallic components for five seconds. At the end of these tests, no evidence of dielectric breakdown or transmission impairment should be evident.

— *Test for surge current resistibility*

A cable sample 1 metre in length shall be immersed in wet sand contained in a non-conducting rigid box having a length of approximately 0.75 metres. The sand shall be 20-40 mesh silica sand, and shall be fully saturated and drained. The cable sample shall be placed in the test box and the wet sand tamped around it. A discharge electrode shall be located near the centre of the test box, between 2.5 and 5.0 cm from the sample. All conducting components in the cable shall be electrically connected together to form one terminal and a test current shall be placed between this terminal and the discharge electrode. It is important for the test current to flow through the sample and to encourage this to occur, any insulating covering over an outer metallic shield or moisture barrier shall be opened with a small slit

or hole facing the discharge electrode. The test current waveform may be either unidirectional or damped oscillatory. The time-to-peak value shall be 15 µs. The frequency of the damped oscillatory current waveform shall be between 16 and 30 kHz, and the time to half-value shall be between 50 and 80 µs. A unidirectional current waveform shall have a time to half-value between 40 and 60 µs. Following the applications of dishcharge currents in ascending amplitudes the sample is tested for loss of its transmission or lowered resistance to moisture penetration. The test identifies a threshold value of surge current which causes cable or transmission deterioration, and assists Administrations to select cables which will be adequately reliable in the light of their experience of damage due to lightning.

4 Protection of remote power-feeding circuits in optical fibre equipment

It is advisable to protect remote-power feeding circuits, e.g. supplied over cables, against overvoltages if disturbance from power lines or lightning is possible. Although the power-feeding circuits are usually symmetrical pairs, the test levels for the associated power-feeding equipment are approximately the same as those for coaxial systems (see Recommendation K.17).

5 Future work

This Recommendation describes the protective measures and calculation methods which can be confirmed at the present time.

Further studies of the problems of protecting optical fibre cables will be made. Work in the following areas, typically, is involved:

— coordinating the protection of cables and working staff against overvoltages due to induction from faults in nearby power lines with that for lightning protection. Limits and precautions for staff and cable protection as given in the *Directives* [2] are applicable also for optical fibre cables with metal parts as far as power induction is concerned. See also Question 6/V in Study Group V for Study Period 1988-1992;

— prediction of trouble rates expected on optical fibre cables. See also Question 22 in Study Group V for Study Period 1988-1992 and the Contribution COM V-58, 1987, which will be considered.

References

[1] CCITT manual *The protection of telecommunication lines and equipment against lightning discharges* , ITU, Geneva, 1974, 1978.

[2] CCITT manual *Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines* , ITU, Geneva, 1988.

Recommendation K.26

PROTECTION OF TELECOMMUNICATION LINES AGAINST HARMFUL EFFECTS FROM ELECTRIC POWER AND ELECTRIFIED RAILWAY LINES

(Melbourne, 1988)

The CCITT draws attention to the need for adequate and reliable protection to be given to telecommunication facilities to guard them against danger and disturbance arising from nearby electric power or electrified railway lines. The danger and disturbance can arise due to conductive, capacitive or inductive coupling between the systems, and the safety of people using or working on telecommunication installations needs to be assured.

To meet this need, the CCITT has issued the *Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines* , Geneva, 1988, which provide guidance in estimating possible overvoltages or overcurrents and recommending limiting values for these conditions. The *Directives* also give advice on methods used to measure overvoltages, overcurrents and relevant parameters, on protective devices and on protection methods and safety precautions.

The *Directives* (1988 edition) consist of nine volumes listed below:

Volume I — Design, construction and operational principles of telecommunication, power and electrified railway facilities

Volume II — Calculating induced voltages and currents in practical cases

Volume III — Capacitive, inductive and conductive coupling: physical theory and calculation methods

Volume IV — Inducing currents and voltages in power transmission and distribution systems

Volume V — Inducing currents and voltages in power transmission and distribution systems.

Volume VI — Danger and disturbance

Volume VII — Protective measures and safety precautions

Volume VIII — Protective devices

Volume IX — Test and measuring apparatus and methods.

These volumes have been established by the CCITT in close cooperation with the International Conference on Large High Voltage Electric Systems (CIGRE) and the International Union of Railways (UIC).

The CCITT recommends that, when telecommunication installations are expected to be affected by nearby power or electrified railway lines, Administrations will find it in their own interest to observe the methods given in the *Directives* (1988 edition).

The *Directives* (1988 edition) replace the *Directives concerning the protection of telecommunication lines against harmful effects from electricity lines* , (Geneva, 1963, amended and supplemented in 1965, 1974, 1978 and 1982).

Blanc