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SERIES K: PROTECTION AGAINST INTERFERENCE

ITU-T K.44 – Test conditions and methods information

ITU-T K-series Recommendations – Supplement 17

Supplement 17 to ITU-T K-series Recommendations

ITU-T K.44 – Test conditions and methods information

Summary

Supplement 17 to ITU-T K-series Recommendations provides background information that explains how the various lightning and power fault test configurations and electrical values in Recommendation ITU-T K.44 were derived. Examples show how test procedures can be minimized by knowing how the surge and power fault test conditions can vary with time and voltage. How ITU-T Recommendation K.44 relates to its dependent Recommendations is explained.

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[*] To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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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.

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Supplement 17 to ITU-T K-series Recommendations

ITU-T K.44 – Test conditions and methods information

1   Scope

This Supplement provides information on:

- the rationale for the various port testing configurations;
- typical port protection function operation under lightning and power fault tests and how this knowledge may be used to minimise test procedures;
- the use of coupling/decoupling networks to control the stress levels on connected auxiliary items;
- alternating current (a.c.) mains distribution types and their influence on a.c. mains port testing configurations;
- the range of lightning and power induction test levels used;
- relationship between [ITU-T K.44] and other product or product family Recommendations.

2   Reference

[ITU-T K.44]   Recommendation ITU-T K.44 (2018), *Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation*.

3   Definitions

3.1   Terms defined elsewhere

This Supplement uses the terms defined in [ITU-T K.44].

4   Abbreviations and acronyms

This Supplement uses the abbreviations and acronyms defined in [ITU-T K.44].

5   Conventions

None.

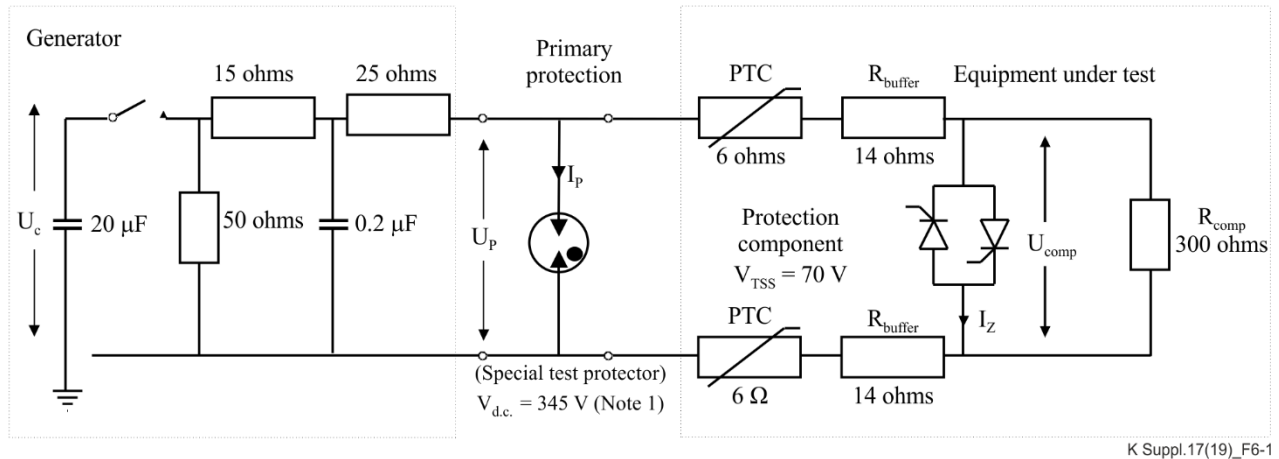## 6   Testing

6.1   General

To check that equipment fulfils the specified acceptance criteria for all voltage and current levels up to the maximum test level, it is necessary to either test at a large range of test voltages or currents from zero to the maximum level specified, or to perform "intelligent testing". Clauses 6.2 to 6.4 provide information on intelligent testing which minimizes the number of test levels, but ensures that sufficient tests are performed.

6.2   Lightning surge tests

To check that no damage windows exist within the equipment, it is necessary to perform tests at specific test voltages. These specific test voltages are determined by the operating points of such components as the primary protector (GDT or SSA) and switching protective devices within the equipment. Examples of these test voltages are illustrated using an example of a linecard with a 6 Ω

PTC thermistor and a 14 Ω resistor in series (20 Ω in total) and with a shunt switching type inherent protector. This example linecard, along with the test generator and the primary protector, is shown in Figure 6-1. Apart from the test generator, all the circuit layout and component values have been chosen only for explanatory purposes and are not put forward as recommended practice.

When the charging voltage U_c is progressively raised, the different components are subjected to different voltages, currents and energies.

NOTE 1 – Special test protector for 230 V primary protector.
NOTE 2 – In practice the total resistance of R_{buffer} + the PTC may vary from 10-100 ohms and R_{comp} may also have different values.

Figure 6-1 – Example linecard with designated voltages and currents

The circuit in Figure 6-1 is an example of a linecard with a low-input impedance when the inherent protection operates. The equipment is nominally protected in exposed areas with an SSA or a GDT on the MDF. It is assumed that it will be protected with a 230 V GDT and the primary protector has been replaced with a GDT with a 345 V d.c. sparkover voltage as described in clause 8.4.1 (i.e., 300 V d.c.$_{mx}$ multiplied by 1.15). The circuit shown is for a transverse or differential test, see Figure A.6.1-1a of [ITU-T K.44]. To keep the circuit simple, neither coupling or decoupling elements, nor auxiliary equipment, have been shown. The figures shown are for positive polarity surges only. The 300 Ω resistor R_{comp} represents the transverse or differential impedance of the components to be protected.

R_{buffer} is an additional resistor. The value of the total resistance of R_{buffer} plus the PTC thermistor may vary in practice from 10 to 100 Ω. This resistor, in conjunction with the PTC thermistor, provides a buffer impedance between the primary protection and the inherent protection to achieve coordination. The input impedance (resistance) of the EUT when inherent protection turns on is 2 × (6 + 14). In some applications, it is possible that the PTC thermistors and resistors R_p will be at the MDF with the primary protection. Note that having PTC thermistors and resistors R_p at the MDF is not recommended practice as some operators may have MDFs that do not accept series impedance. Also, it is better for the PTC thermistors to be at the temperature of the linecard. However, there may be some circumstances where PTC thermistors or other types of overcurrent protection need to be installed on the MDF (see [b-ITU-T K.82] for guidance).

R_{comp} is the resistance of the circuit. Its value may vary with current and frequency. However, it is usual that the maximum current which flows through R_{comp} is less than 0.2 A. This current is negligible compared to the current, which is conducted by the inherent protection when it operates.

The inherent protection is a thyristor-type device.

To thoroughly test the resistibility of the equipment, it is necessary to test the equipment at a number of different values for U_c.

6.2.1 Inherent test

The value of U_c is given in the product Recommendation. The generator is set to apply the required surges.

6.2.2 Secondary protector coordination test

If the equipment contains a switching type inherent protector, e.g., a thyristor, the value of U_c is adjusted to generate a surge just less than that which will turn on the switching type protector. In the example linecard, the thyristor will turn on if the voltage across it exceeds its switching voltage, usually around 70 V. After the thyristor turns on, the voltage drop is only 1 or 2 V.

A U_c of 90 V produces 69 V across R_{comp} and no current flows in the thyristor, see Figure 6-2. This is the point of worst stress for the components and 10 surges of alternate polarity should be applied.
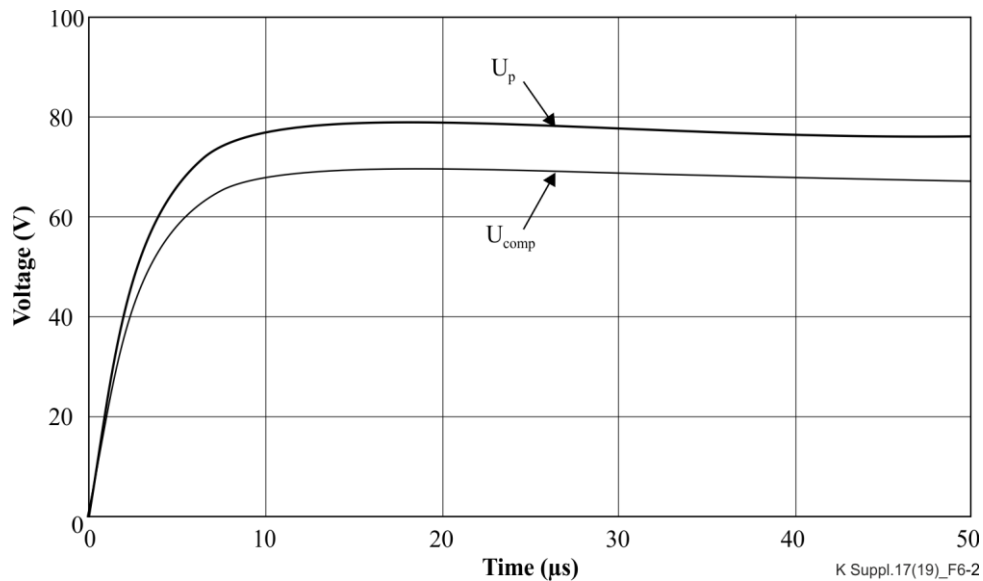

Figure 6-2 – Voltages with U_c to give a U_{comp} of 69 V

With a U_c of 92 V, the voltage across R_{comp} exceeds 70 V, the inherent protection operates and current is conducted through the PTC thermistors and the 14 Ω resistors, see Figure 6-3. This will limit the voltage across the components to be protected to 70 V.
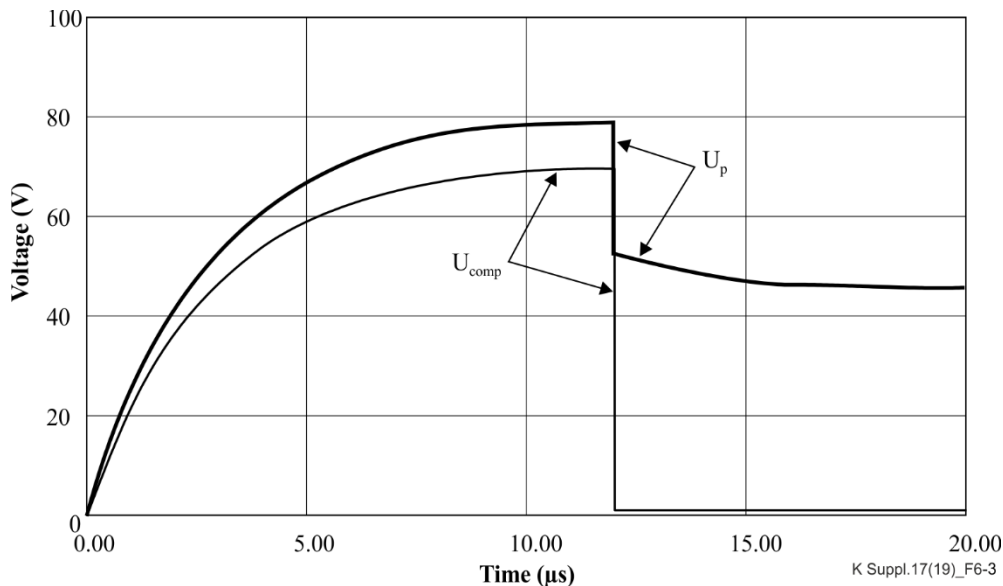
Figure 6-3 – Voltages with U_c to give a U_{comp} of 70 V

6.2.3 Primary protector coordination test

If the equipment is protected by a switching type primary protector, e.g., a GDT, the value of U_c is adjusted to generate a surge just less than that which will turn on the switching type protector. By increasing the charging voltage U_c, the voltage across the PTC thermistors and the 14 Ω resistors, as well as the current through the PTC thermistors and the resistors, will increase until the charging voltage is just below the activation level of the primary protection, see Figure 6-4. In the example linecard, a charging voltage, U_c, of 843 V is the point of maximum stress for the PTC thermistors and the 14 Ω resistors, and 10 surges of alternate polarity should be applied. Figure 6-4 shows the maximum full-wave 10/700 µs voltage which appears at the input of the equipment.
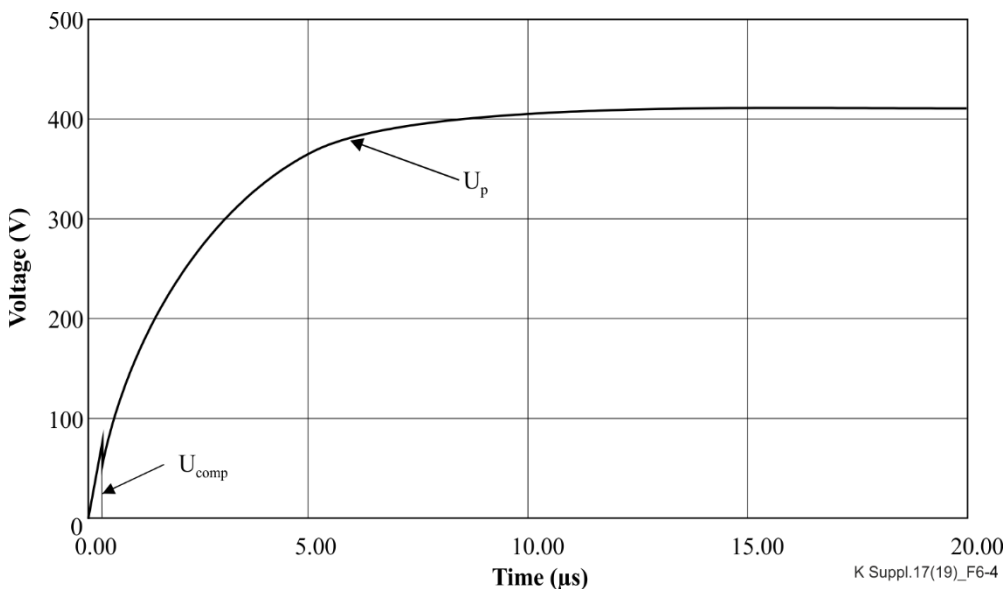

**Figure 6-4 – Voltages with U_c set to cause a U_p just below the
sparkover voltage of the gas discharge tube**

With a U_c of 855 V, the primary protection is activated, the voltage U_p drops to a lower value (typically about 25 V). The current I_z flowing into the equipment falls to a very low value and becomes practically independent of U_c.

Figure 6-5 shows the measured voltage U_p across the primary protection and the voltage across the PTC thermistors and the 14 Ω resistors for a charging voltage U_c of 855 V and a GDT with a d.c. breakdown voltage of 345 V, the firing voltage of the special test protector used when the agreed primary protector is a 230 V GDT. The different currents can be calculated from the voltages. The primary protector used was activated after 15 μs and the maximum voltage across the GDT was 420 V.

It should be noted that if the primary protection is not activated during the rising edge, it can still be activated during the decay period, during which the voltage remains initially almost constant. When the GDT is activated during the decay period, the breakdown voltage is lower and approaches the d.c. breakdown voltage.
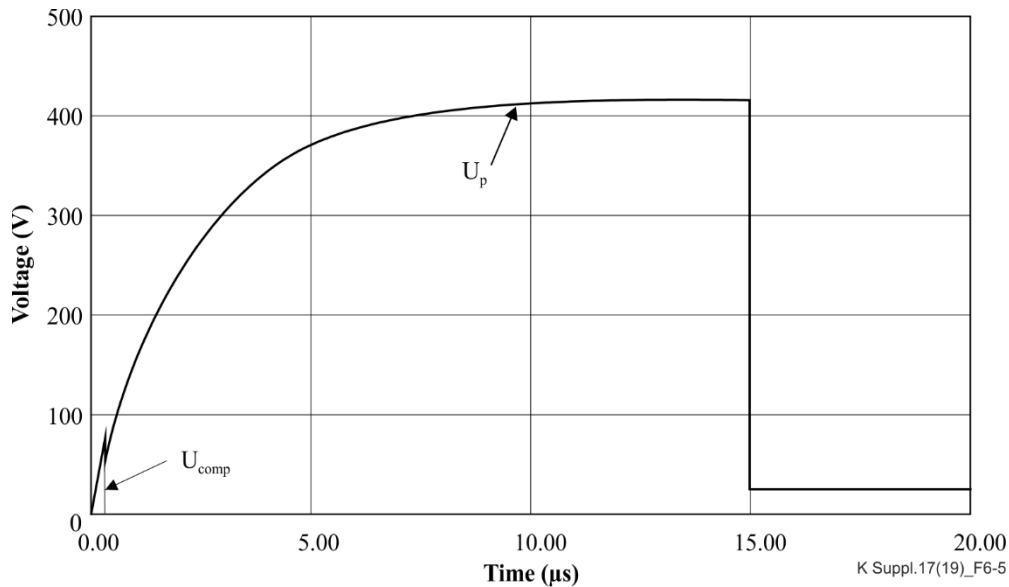

Figure 6-5 – Voltage U_p across the special test protector for a charging voltage U_c of 855 V

6.2.4 $U_{c(max)}$ test

Figure 6-6 shows the measured voltage U_p across the primary protection and the voltage across the PTC thermistors and the 14 Ω resistors for a charging voltage U_c of 4 kV. The primary protection was activated after 1.5 μs and the maximum voltage across the GDT is 632 V. Although the voltage is higher, the level of surge stress that is passed to the equipment is lower.

**Figure 6-6 – Voltage U_p across the special test protector for
a charging voltage U_c of 4 kV**

6.2.5 Effects for voltages greater than $U_{c(max)}$

Figure 6-7 shows the measured voltage U_p across the primary protection and the voltage across the PTC thermistors and the 14 Ω resistors for a charging voltage U_c of 10 kV. The primary protection was activated after 0.5 µs and the maximum voltage across the GDT is 690 V. Although the voltage is higher, the level of surge stress that is passed to the equipment is lower.
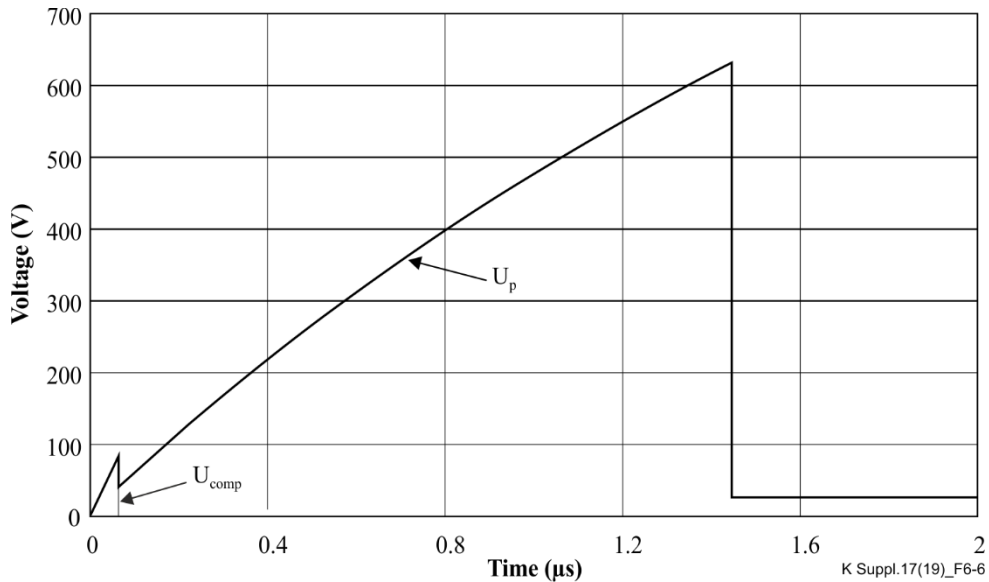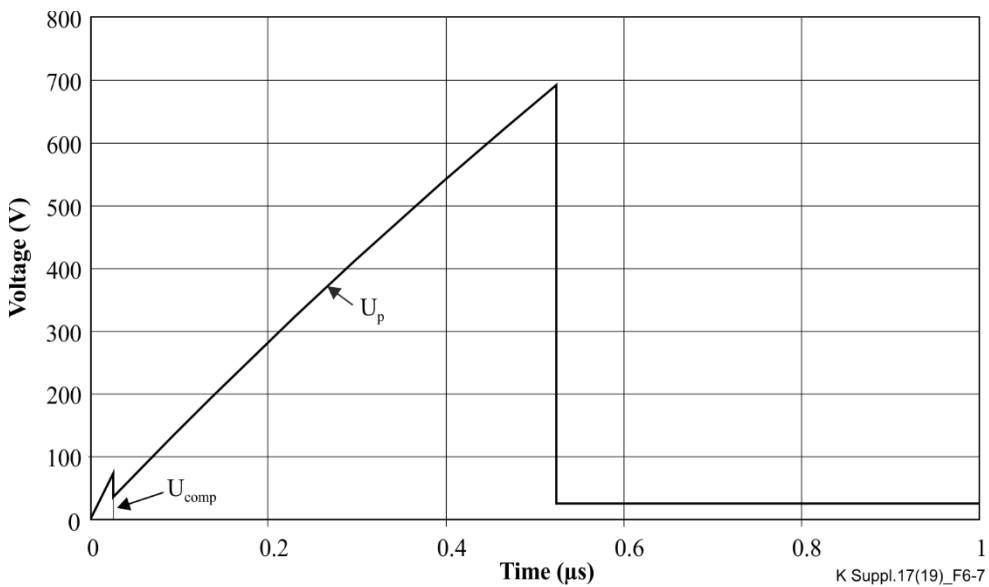

**Figure 6-7 – Voltage U_p across the special test protector for
a charging voltage U_c of 10 kV**

This example with six different charging voltages shows the importance of the knowledge of the characteristics of the primary protection and the inherent protection in order to ensure appropriate coordination between primary and inherent protection, and the equipment.

6.3 Power induction

Induced voltages are more likely to occur on long lines, and in the common case where customer lines do not provide a low resistance to earth, induced voltages, E, may be considered to have a high

source impedance consisting of a 600 Ω wire resistance in series with a 0.33 μF line to earth capacitance as shown in Figure 6-8. The telephone is represented by a 100 Ω resistance and the hook-switch. The GDTs shown in Figure 6-8 are needed only on lines in exposed areas. However, because of the liberalization of CPE, such protectors may also be present on less-exposed lines. These GDTs fire at the customer line end in the short-term power induction case and short-circuit the telephone and the line capacitances. Therefore, the test circuit given in Figure A.3-6 of [ITU-T K.44] consists only of the induced voltage $E = U_{a.c.}$ and the wire resistances R.

Field experience showed that a large number of linecards in some exchanges were damaged by power induction during thunderstorms. The damage appeared only in exposed rural areas. The currents induced on such lines, causing the linecard damage, were measured in a few cases and showed values between 4 and 6 A with duration between 200 and 500 ms, i.e., I^2t values between 10 and 20 A^2s. Figure 6-9 shows measurements of power induction in Australia.

These overcurrents with high I^2t values were estimated as rare events; therefore, it was agreed that the induction test, with agreed primary protection, should simulate an overcurrent with a I^2t of 1 A^2s for the basic requirement and 10 A^2s for the enhanced requirement.

Considering that most test laboratories only had available a test circuit with a maximum test voltage of 600 V, it was decided to define, for the basic requirement induction test, this maximum voltage value $U_{a.c.(max)} = 600$ V and to increase the test duration up to 1 s.
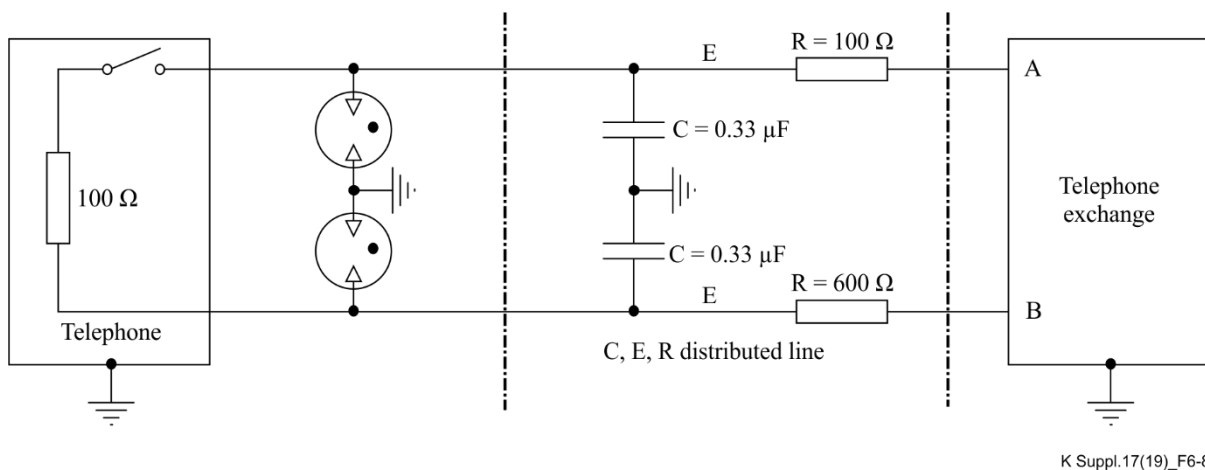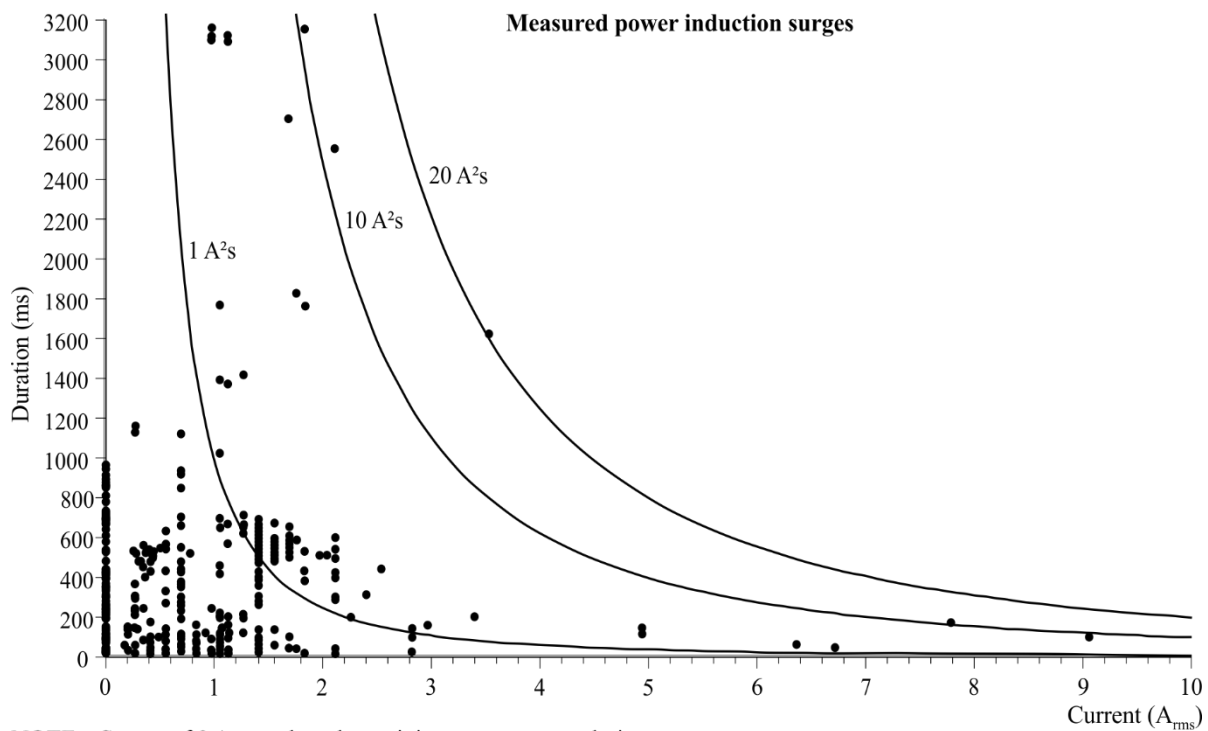

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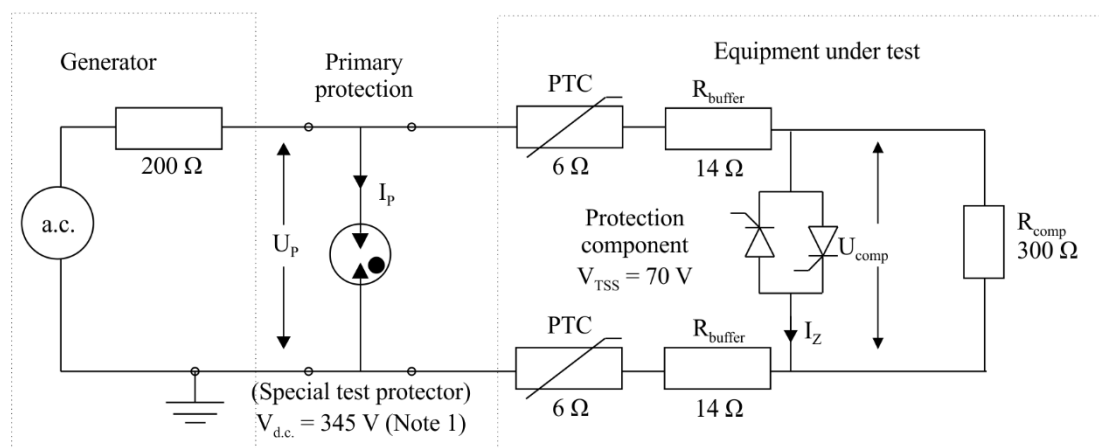**Figure 6-8 – Equivalent circuit of a telecommunication line during power induction**

NOTE – Surges of 0 A were less than minimum current resolution.

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Figure 6-9 – Power induction overcurrents measured in Australia

As with the lightning surge testing, it is also necessary to be aware of the need to test at specific voltage levels when performing power induction tests. An example of a linecard circuit utilizing a PTC thermistor and switching protector is shown in Figure 6-10. During testing, the following points were monitored, U_p, I_p, U_{comp} and I_z, to illustrate the operation of various components. The monitoring internal to the equipment was done to help designers and testers to understand the issues to consider when testing the equipment. It is not necessary to monitor internal to the equipment during type approval testing.

NOTE 1 – Special test protector for 230 V primary protector.
NOTE 2 – In practice the total resistance of R_{buffer} + the PTC may vary from 10-100 Ω and R_{comp} may also have different values.

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Figure 6-10 – Example circuit

As with the lightning surge testing, power induction testing has to be performed at specific test levels.

6.3.1 Inherent test

The value of $U_{a.c.}$ and the duration is given in the product Recommendation. The generator is set to apply the required surges.

6.3.2 Secondary protector coordination test

If the equipment contains a switching type inherent protector, e.g., a thyristor, the value of $U_{a.c.}$ is adjusted to generate a surge just less than that which will turn on the switching type protector. As the test voltage is increased from 0 V, it is noticed that the switching devices start to operate at the peak of the voltage, see Figure 6-11. This may be due to a marginal increase in the generator voltage. A generator voltage just below that which operates the inherent protection for switching and foldback type inherent protection is the point of maximum voltage stress for the components to be protected. Five surges should be applied with the generator voltage set just below that which operates the inherent protection.
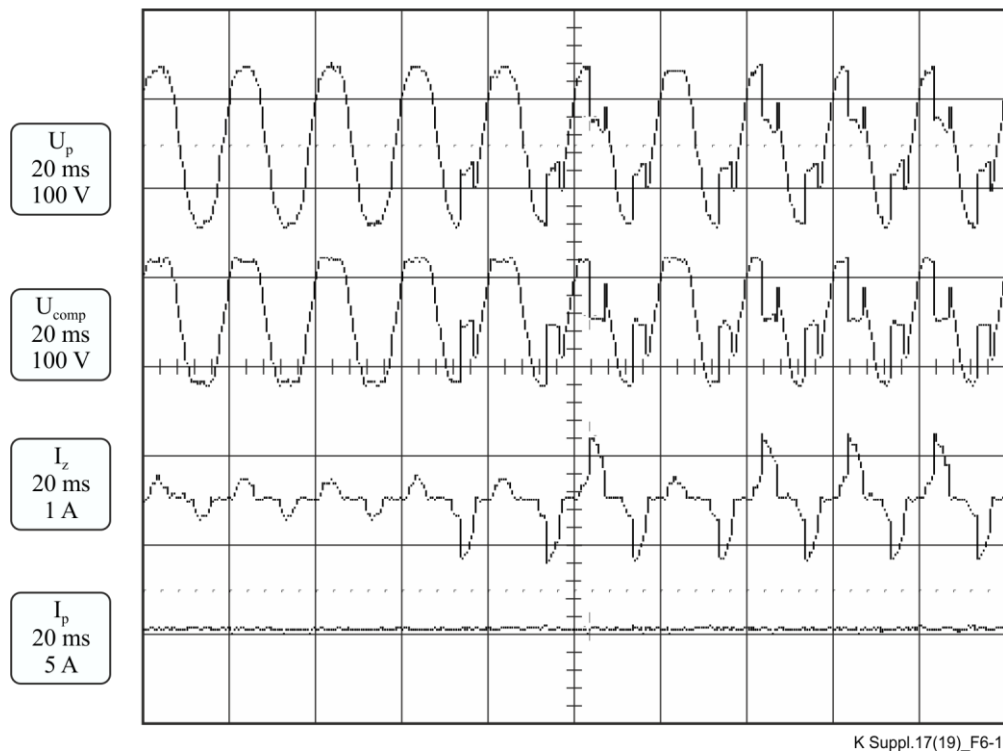

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Figure 6-11 – $U_{a.c.}$ = 127 V_{rms}, switching inherent protector starts to operate

6.3.3 Secondary protector operating test

If the voltage is increased further, it is noticed that the switching devices operate for the whole test period, but there is insufficient heating of the PTC thermistor to cause it to operate, see Figure 6-12. Five surges should be applied with this generator voltage. This test applies whether there are PTC thermistors or not.
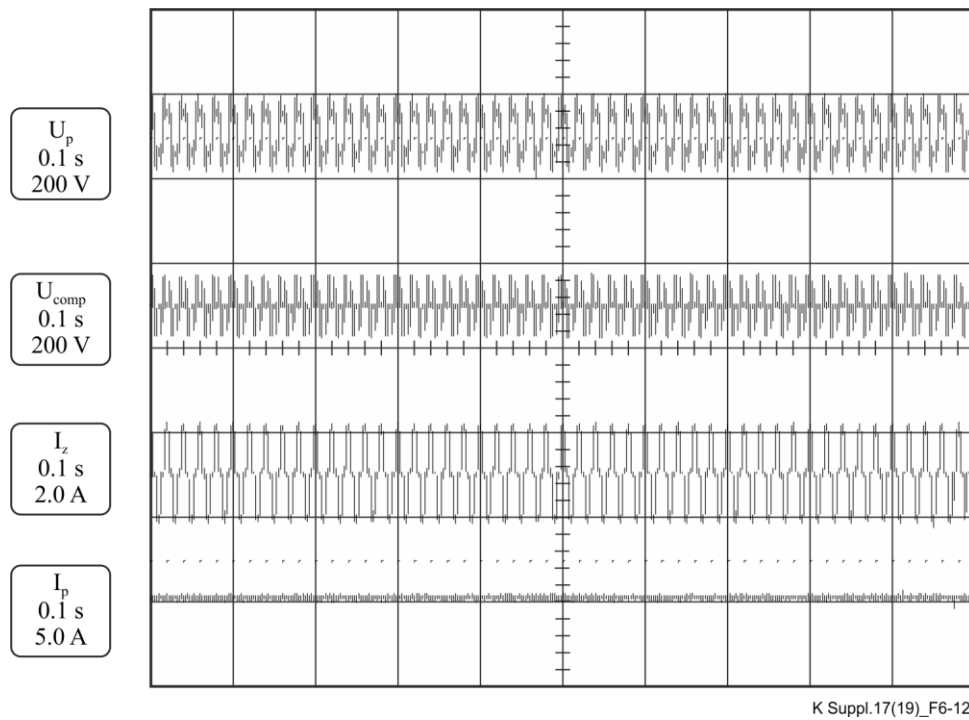
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Figure 6-12 – $U_{a.c.}$ = 200 V_{rms}, switching inherent protector operating, but not positive temperature coefficient thermistor

6.3.4 Minimum energy to operate positive temperature coefficient thermistors

This test only applies to equipment with PTC thermistors. As $U_{a.c.}$ is increased further, the PTC thermistor operates at the end of the test period. In some cases, the value of $U_{a.c.}$ may not be high enough to operate the special test protector, see Figure 6-13. Five surges should be applied with this generator voltage.
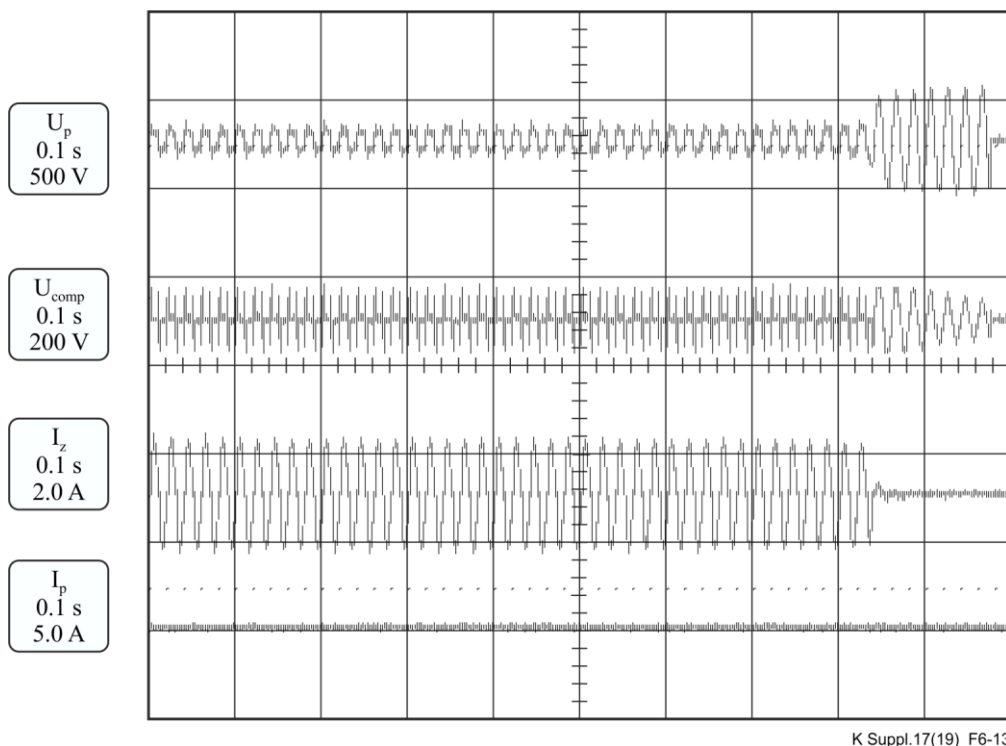

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Figure 6-13 – $U_{a.c.}$ = 220 V_{rms}, positive temperature coefficient thermistor operates at end of test (2 s), below firing voltage of special test protector

6.3.5   Primary protector coordination test

6.3.5.1   Primary protector coordination test for equipment without positive temperature coefficient thermistors

As $U_{a.c.}$ is increased further, the special test protector will begin to operate. $U_{a.c.}$ is reduced by a minimum amount until the special test protector does not operate and five surges should be applied.

6.3.5.2   Primary protector coordination test for equipment with positive temperature coefficient thermistors

As $U_{a.c.}$ is increased further, the special test protector will begin to operate at the end of the test duration, see Figure 6-14. Five surges should be applied with this generator voltage.
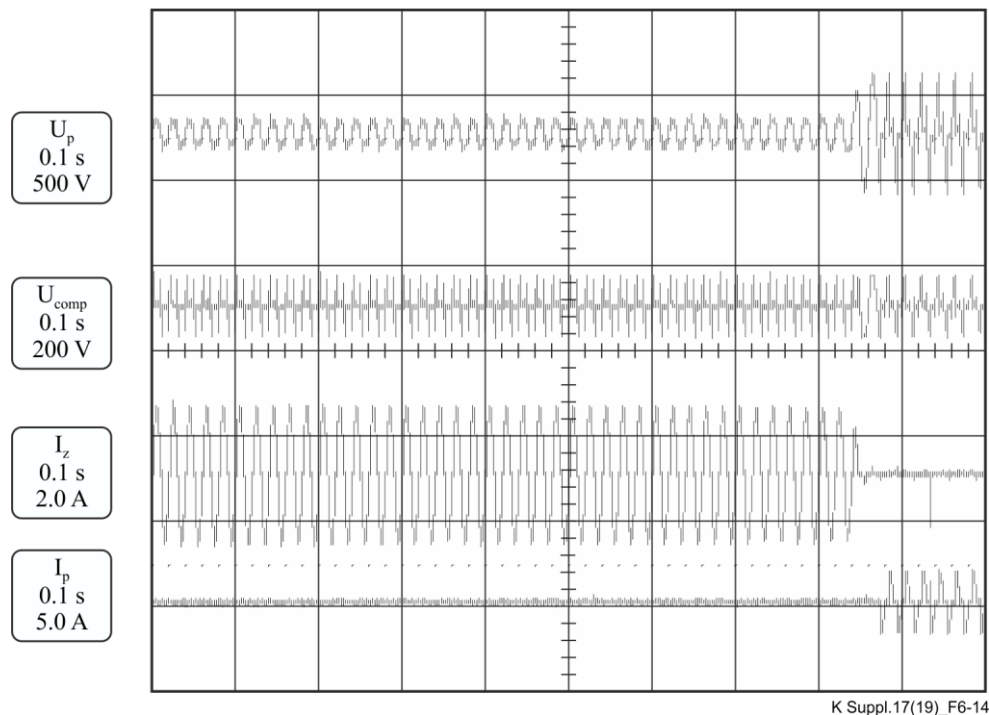

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Figure 6-14 – $U_{a.c.} = 280\ V_{rms}$, special test protector operating

6.3.6 $U_{a.c.(max)}$ test

It is also necessary to apply five surges with the generator set to $U_{a.c.(max)}$, as this is the point of maximum current stress for the PTC thermistor.

In all cases where the PTC thermistor operates, it may be necessary to wait approximately 15 min between surges to allow the PTC thermistor to cool.

6.4   Mains power contact

Mains power contact surges can occur up to the amplitude of the mains voltage. The maximum voltage is nominally 240 V_{rms}. The resistance between the source and the equipment is thought to be anywhere from 10 Ω to 1 000 Ω.

Direct contact with electrical mains power can occur through network lines or cable faults, faulty or unapproved CPE, or other causes. The contact may not cause the operation of a power system circuit breaker. The a.c. currents resulting from 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.

The following particular dangers to equipment may arise.

–   A contact near to the equipment where the combined resistance of the cable circuit and equipment termination is low and a high current flow occurs. This condition is simulated in the test in Figure 6-15 by a resistance of 10 Ω. The test current may be limited to lower values according to national regulations.

–   A contact at the maximum distance from the equipment where the combined resistance of the cable circuit and equipment termination is high, and a small but harmful current flows continuously. This condition is simulated by a resistance of 1 000 Ω.

–   Experience shows that, in reality, with values between 10 and 1 000 Ω, equipment is most susceptible to damage and fire hazard from current overheating.

Mains power contact generally has a source voltage equal to the local mains voltage. The resistance between the source and the linecard consists of the line resistance and the fault contact resistance. Experience has shown that the worst-case situation can occur over a narrow resistance range. To ensure that the worst-case condition is checked, the following test resistor values are used: 10 Ω, 20 Ω, 40 Ω, 80 Ω, 160 Ω, 300 Ω, 600 Ω and 1 000 Ω.
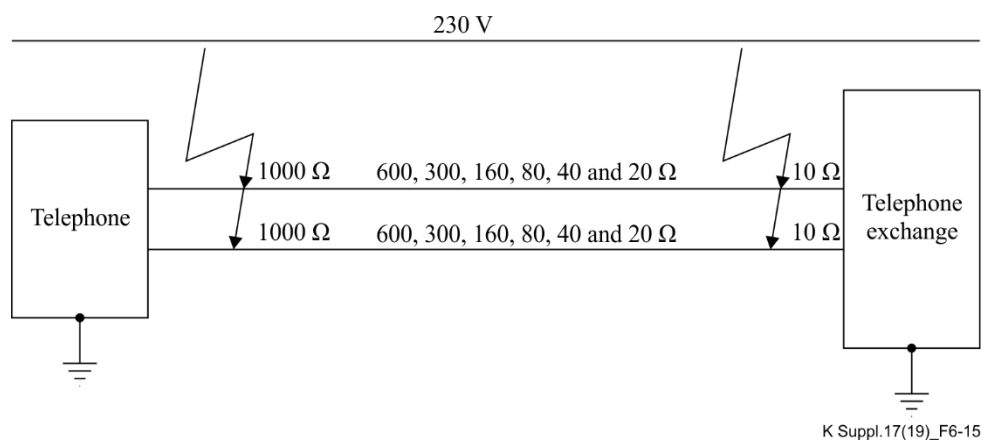

Figure 6-15 – Mains power contact mechanism

It was agreed during the study period to perform the power contact with these eight resistor values as a result of a problem experienced by British Telecom. However, because the power contact test has a duration of 15 min, it was decided that testing with all eight resistors was too onerous and that the choice of intermediate resistors should be up to the person performing the test. There was also some discussion on reducing the test duration where it does not affect the test result. In this case, some guidance needs to be given on choosing the test resistor and test duration.

There are three known design methods for complying with the power contact test and these are: use of an ECL, use of a PTC thermistor, or use of a fusible link in series with the line current. For both the fuse link and the PTC thermistor, the worst case, from a circuit viewpoint, is the test resistor which results in maximum transfer of energy into the circuit. This can be determined by testing with all test resistor values and determining the maximum energy with an oscilloscope by measuring the voltage at the input of the circuit and current flowing into the circuit, and then integrating the product of the voltage and current with time.

a)   A fusible link or resistor is designed to overheat and break open, interrupting excessive current flow into the equipment. Where minimal testing is done, the test should be performed with the 10 Ω resistor and with the test resistor that causes the maximum heat energy dissipation in the circuit. Where it is proven that the resistor will not contract and reconnect the circuit when it has cooled, the test may be stopped once the current is interrupted.

b)   A PTC thermistor is designed to become "high resistance" when an excessive current flows through it. The worst-case current for a PTC thermistor is the lowest resistor, i.e., the highest

peak current. Where minimal testing is to be performed, the test should be performed with the test resistor which causes the maximum energy dissipation in the circuit, and with the 10 Ω resistor.

Generally, once a PTC thermistor has operated, the current will be limited to low values and there will be no change for the remainder of the test. However, there have been cases where the PTC thermistor has started to break down at the end of the duration, which can cause excessive heating and the possibility of a fire. Also, there have been cases where the PTC thermistor forms a relaxation oscillator with a long time constant. However, where it is proven that the PTC thermistor will not fail within the test time, or that there is no other factor that will alter the test result, the test may be stopped once the current has stabilized at a low value, which will prevent an overheating situation.

If the worst-case resistor cannot be determined, the test should be performed with all resistor values.

6.5 Rationale for test conditions

6.5.1 Port to port and port to earth testing

Correctly testing equipment is a complex task. There are many types of equipment construction practices, equipment locations, and earthing and bonding practices.

Equipment can generally be classified as earthed or floating (not earthed).

Equipment may be installed in a telecommunication centre where the resistance to earth is likely to be <2 Ω, in the access or trunk network, where the resistance to earth may be as high as 30 Ω or in a customer premises, where the resistance to earth may be as high as 300 Ω.
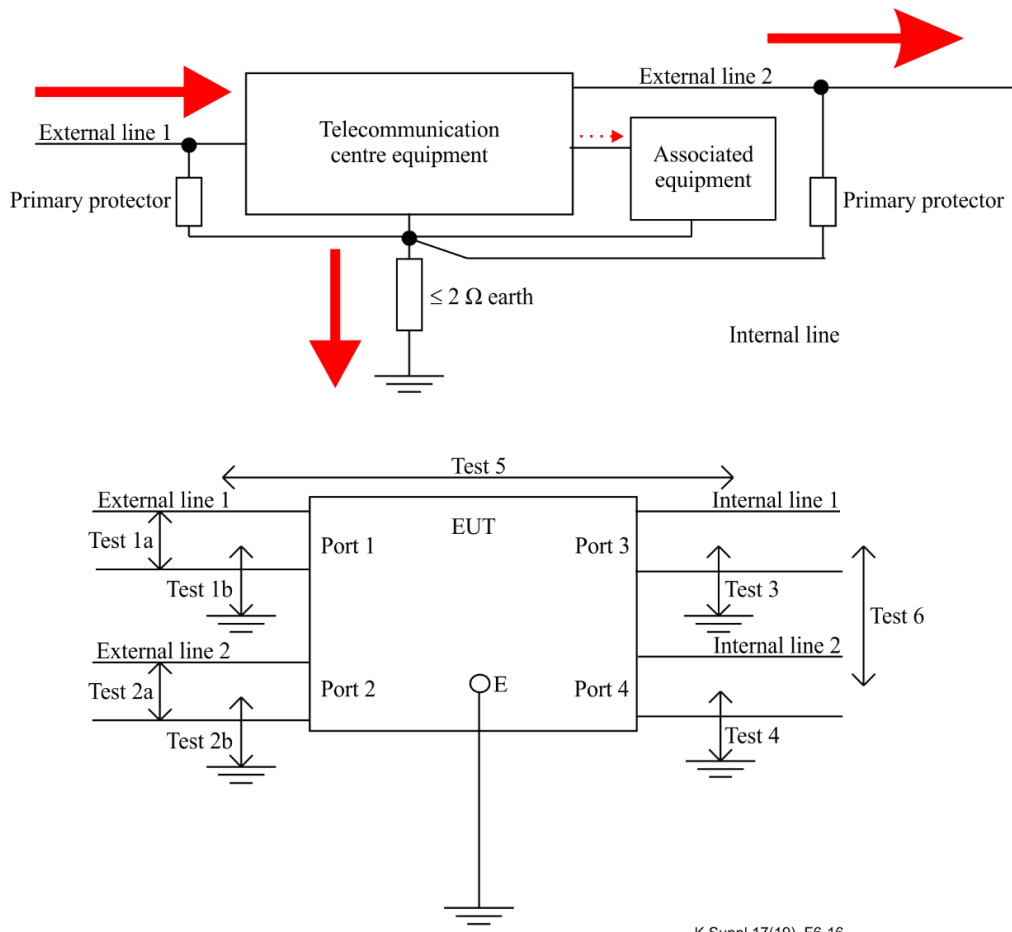
In some countries, an IT or TT power distribution system may be used. In these cases, the power network is not bonded to the customer premises earthing system. This is sometimes referred to as a separated earth system.

Whether the equipment is earthed, the resistance to earth of the installation affects the distribution of the incoming surge current. This distribution of surge current determines the required test method, see Figures 6-16 to 6-18.

In Figure 6-16, a telecommunication centre has a resistance to earth of ≤2 Ω; it can be seen that the majority of the surge current will be conducted external port to earth. Therefore, it is only necessary to perform line to line and port to earth tests on the external ports of the equipment. Note that the external port to internal port test of clause 7.2 is included in the external port to earth test. For internal ports, it is only necessary to test internal ports to earth. Note that the internal port to internal port test of clause 7.2 is included in the internal port to earth test.

In Figure 6-17, it can be seen that for earthed access network equipment, a significant current may be conducted from both port to earth and port to port. Therefore, it will be necessary to perform line to line, port to earth and port to port tests. For floating access network equipment, while substantial current is only conducted port to port on the external ports of the equipment, to check for capacitive current effects, it is still necessary to perform port to earth tests as well.

Figure 6-18 shows that for earthed customer equipment, a significant current may be conducted from both port to earth and port to port. Therefore, it will be necessary to perform line to line, port to earth and port to port tests. For floating customer equipment, while substantial current is only conducted port to port on the external ports of the equipment, to check for capacitive current effect, it is also necessary to perform port to earth tests.

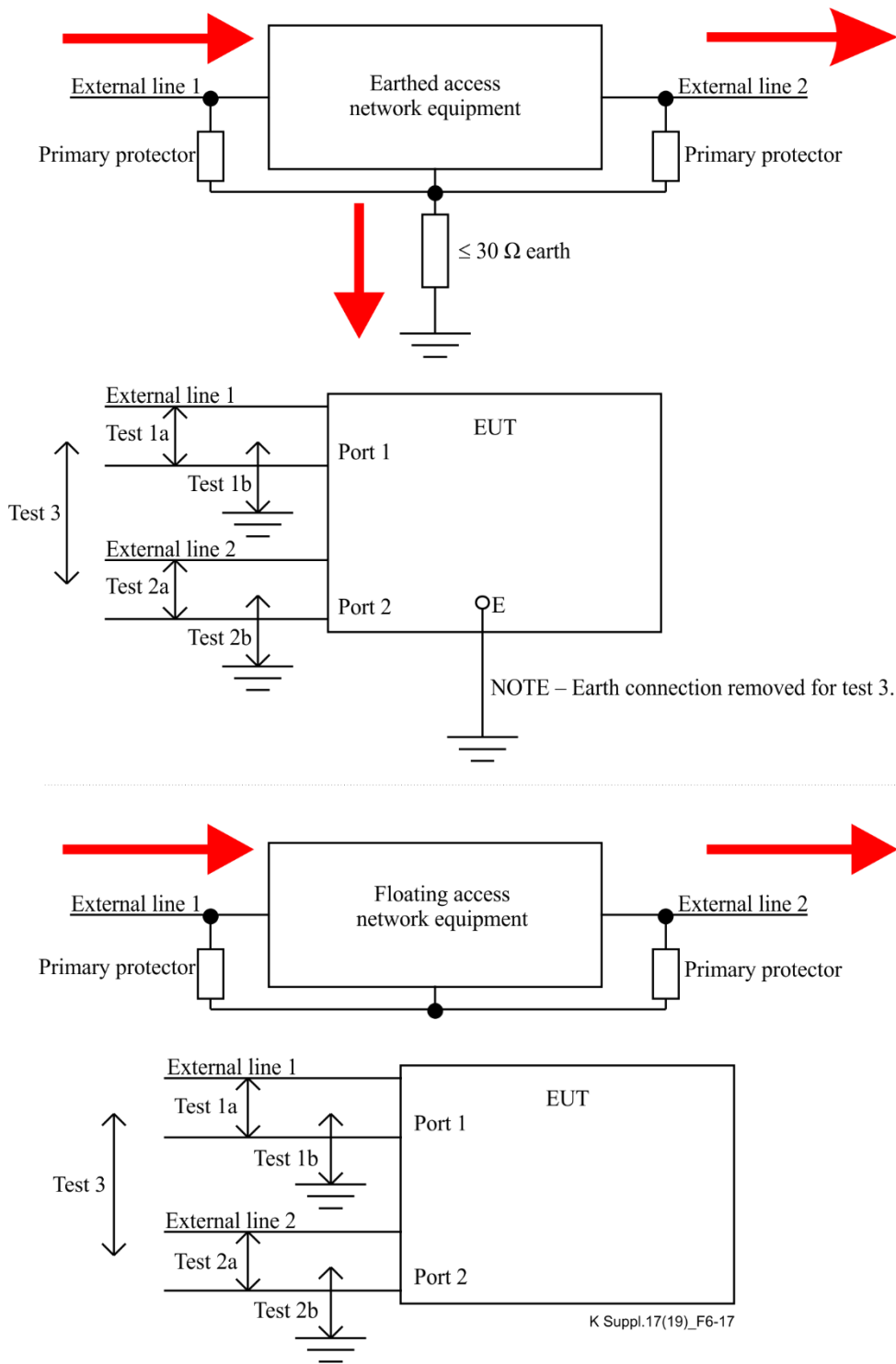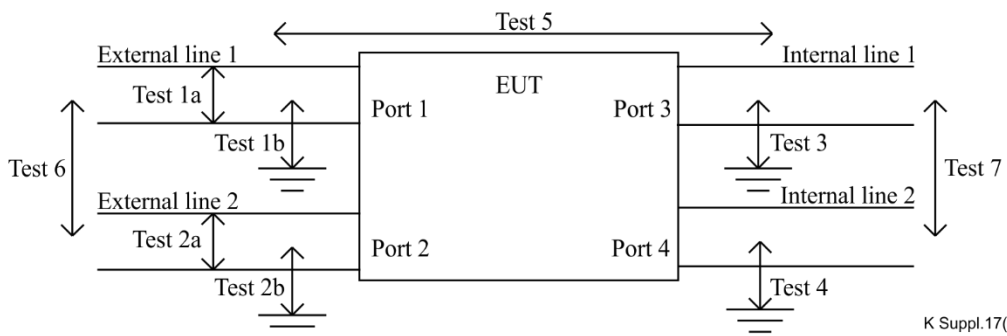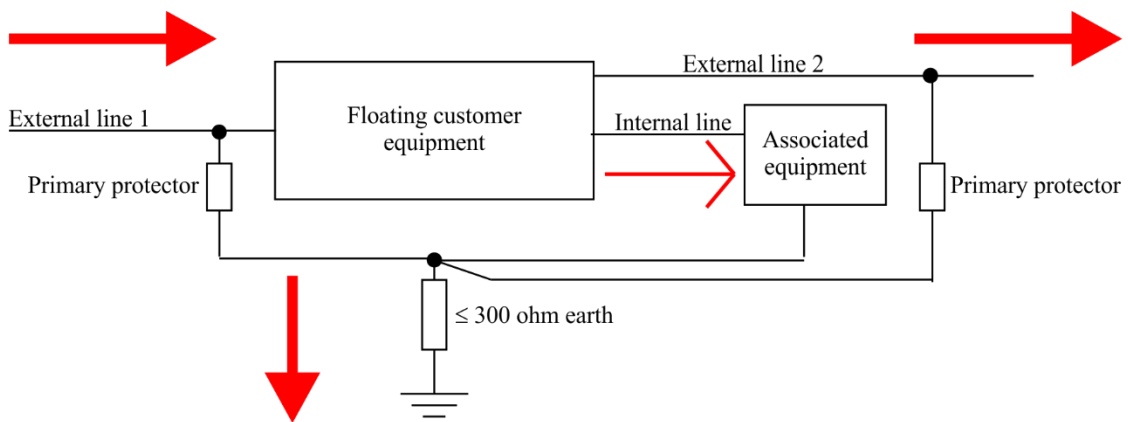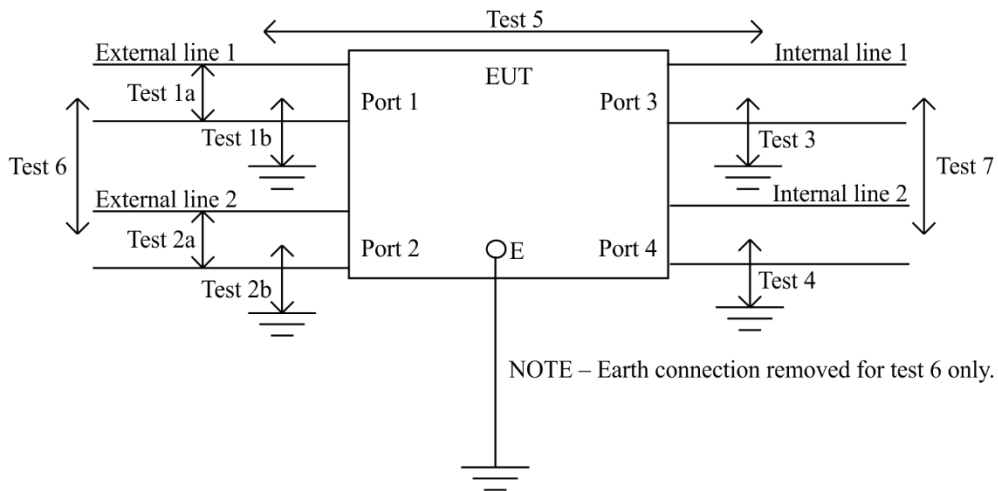**Figure 6-16 – Test conditions for telecommunication centre equipment**

External line 1

Earthed access
network equipment

External line 2

Primary protector

Primary protector

≤ 30 Ω earth

External line 1

Test 1a

EUT

Test 1b

Port 1

Test 3

External line 2

Test 2a

Port 2   ○E

Test 2b

NOTE – Earth connection removed for test 3.

External line 1

Floating access
network equipment

External line 2

Primary protector

Primary protector

External line 1

Test 1a

EUT

Test 1b

Port 1

Test 3

External line 2

Test 2a

Port 2

Test 2b

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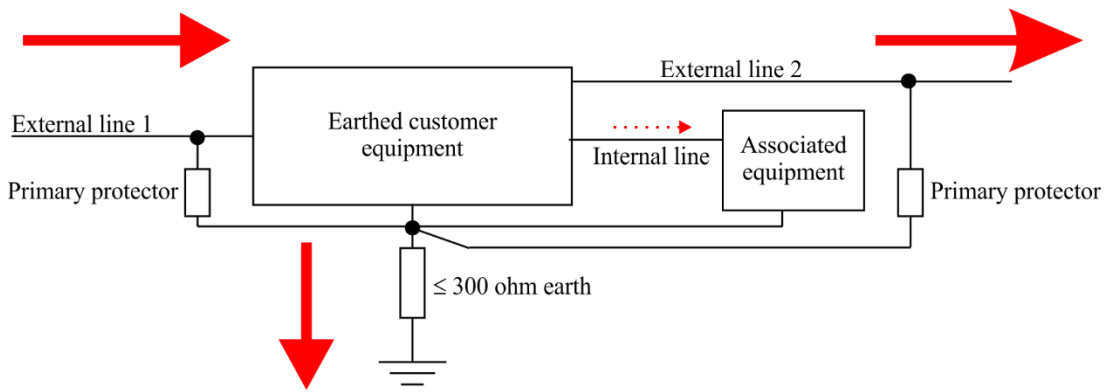**Figure 6-17 – Scenario for outdoor equipment**

Figure 6-18 – Scenario for customer equipment

6.5.2 Terminations and surge protective devices on untested ports

Figure 6-19 shows the possible ports of a complex piece of equipment.

This equipment has both external and internal ports, and the influence of these on the port being tested has to be considered. The EUT may be connected to auxiliary equipment within the same building via internal cables, or to equipment in another building via external cables. SPDs may be used on both types of ports, see Figure 6-19.
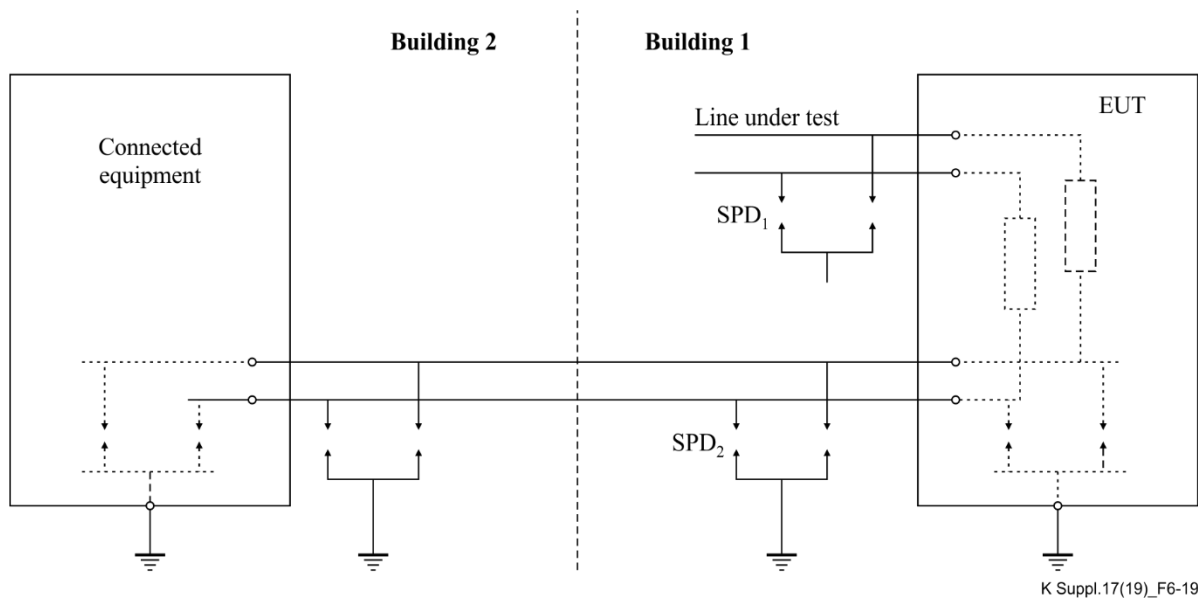

Figure 6-19 – Terminations and surge protective devices on equipment

During testing, ports will need to be both terminated by connection to auxiliary equipment or by a terminating impedance or resistance, and connected to earth by a coupling element in turn. It is necessary to consider the differences between external ports and internal ports. Internal ports are considered to be connected to equipment that has the same reference point as the equipment being tested. External ports, on the other hand, can be connected to equipment with a different earth reference, e.g., in another building. This means that current may be conducted into one external port and out of another external port.

Issues to consider when terminating the equipment or earthing a port are as follows.

1) When there is a possible low impedance path from the port being tested to an untested port, the possibility of the protector on the untested port operating first needs to be considered. This is done by using a special test protector on the tested port and a protector with the minimum allowed d.c. sparkover voltage on the untested port.

2) When there is more than one type of untested port, only one type of untested port should be terminated or have SPDs added at a time. The reason for this is that a low impedance path to one type of untested port may prevent current flow to another type of untested port.

3) Where one port may be connected internally to another port, e.g., under some operating conditions or power fail conditions, this port should be tested with the other port terminated and protected.

4) Where the equipment has high current-carrying protection components, which eliminates the need for primary protection, it is necessary to remove the GDT on the port under test and replace it by the test protector as described in clauses 8.2, 8.3 and 8.4. This is to ensure that coordination has been achieved. During testing of this port, the integral protector is to be left in position for untested ports. If this component is not removable, all tests are performed with the protection provided and the manufacturer must provide a test report to show that the

inherent and coordination tests were performed with the special test protector during the design tests.

5) Tests may need to be applied with the following three combinations of termination and coupling to earth of the untested ports, i.e.:

    a) no termination and no coupling to earth;

    b) no coupling to earth, add a termination;

    c) both coupling to earth and a termination.

It is necessary in port to port testing to consider the following as the second port:

1) other lines or pairs of the port type being tested;
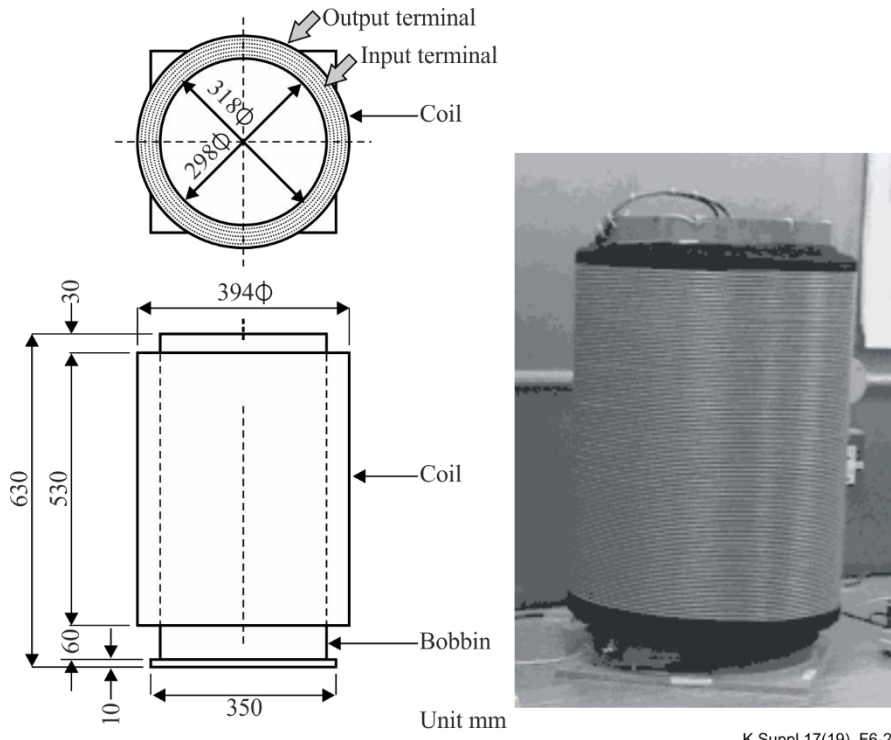
2) lines or pairs of other port types.

6.6 Decoupling networks

6.6.1 Decoupling inductance

The following is information on a 20 mH common mode inductor that could be used for decoupling symmetric pair ports as suggested by [b-IEC 61000-4-5]. Resistors can also be used to achieve decoupling, and are the preferred method.

The decoupling element affects the transmission in high-speed networks due to the resistance, the capacitance and the inductance of the decoupling element. This clause describes a common mode choke coil, whose value is 20 mH and described in [b-IEC 61000-4-5] for use as an inductor. However, the details of the inductor are not described in [b-IEC 61000-4-5], although the characteristics of the inductor are dependent on its configuration.

Figure 6-20 shows the configuration and size of the described coil. The specifications of the element of the coil are summarized in Table 6-1. In order to avoid the saturation of inductance and make the stray capacitance smaller, the coil is an air core type. The common mode impedance frequency characteristics are shown in Figure 6-21. The impedance is greater than 1 kΩ from 10 kHz to 200 kHz. The normal mode impedance is shown in Figure 6-22. The impedance is about 120 Ω. Frequency characteristics of the inductance and transmission loss are shown in Figures 6-23 and 6-24, respectively. The resonance occurs at approximately 46 kHz, but the transmission loss is smaller than 5 dB under 1 MHz.
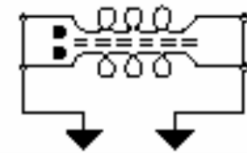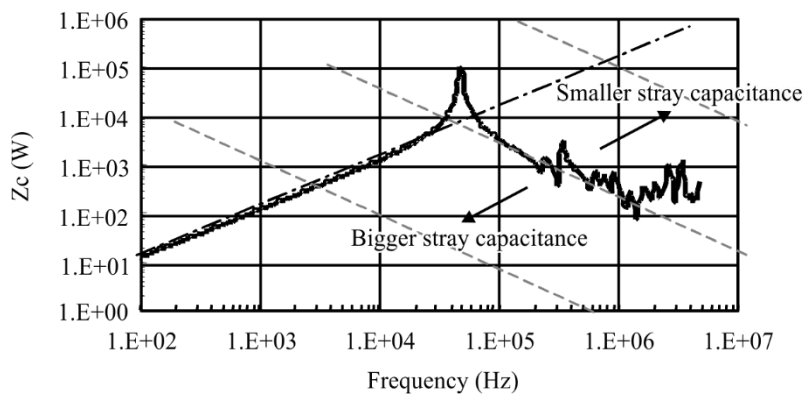
Figure 6-20 – Configuration, size and overview of 20 mH coil

Table 6-1 – Specifications of coil

Items		Specifications
Wire	Material	Copper
	Sectional area	2 mm^2
How to turn		One pair of lines turned together
Turns		48 turns × 7 layers
Inductance		20 mH (common mode)

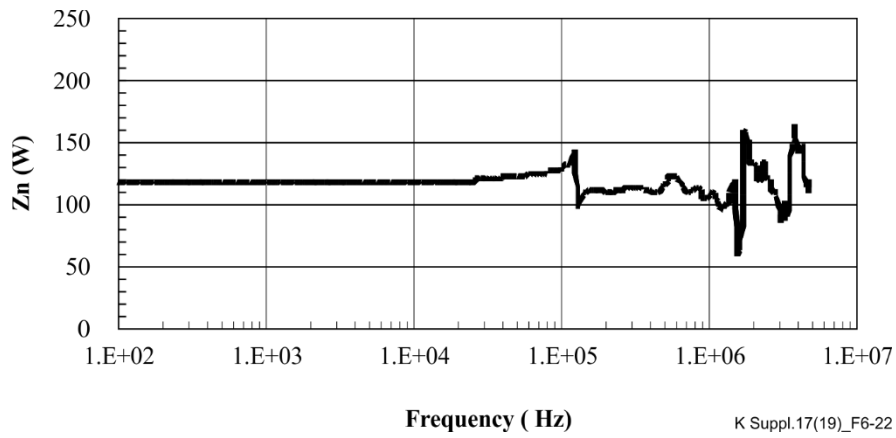**Figure 6-21 – Common mode impedance**

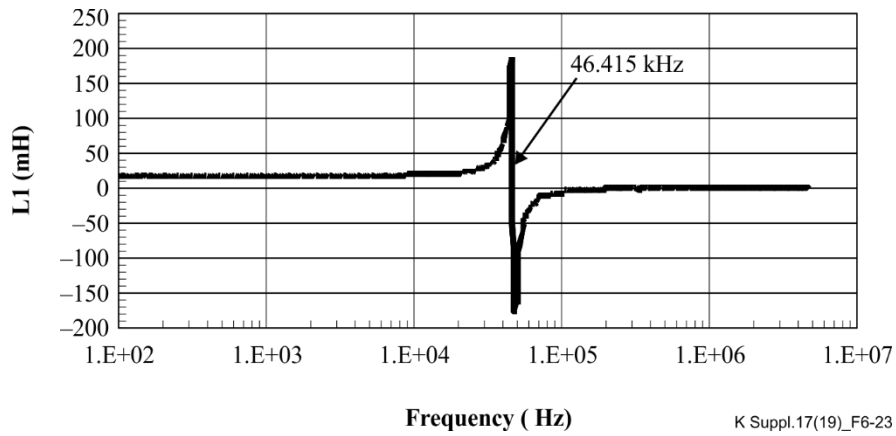**Figure 6-22 – Normal mode impedance**

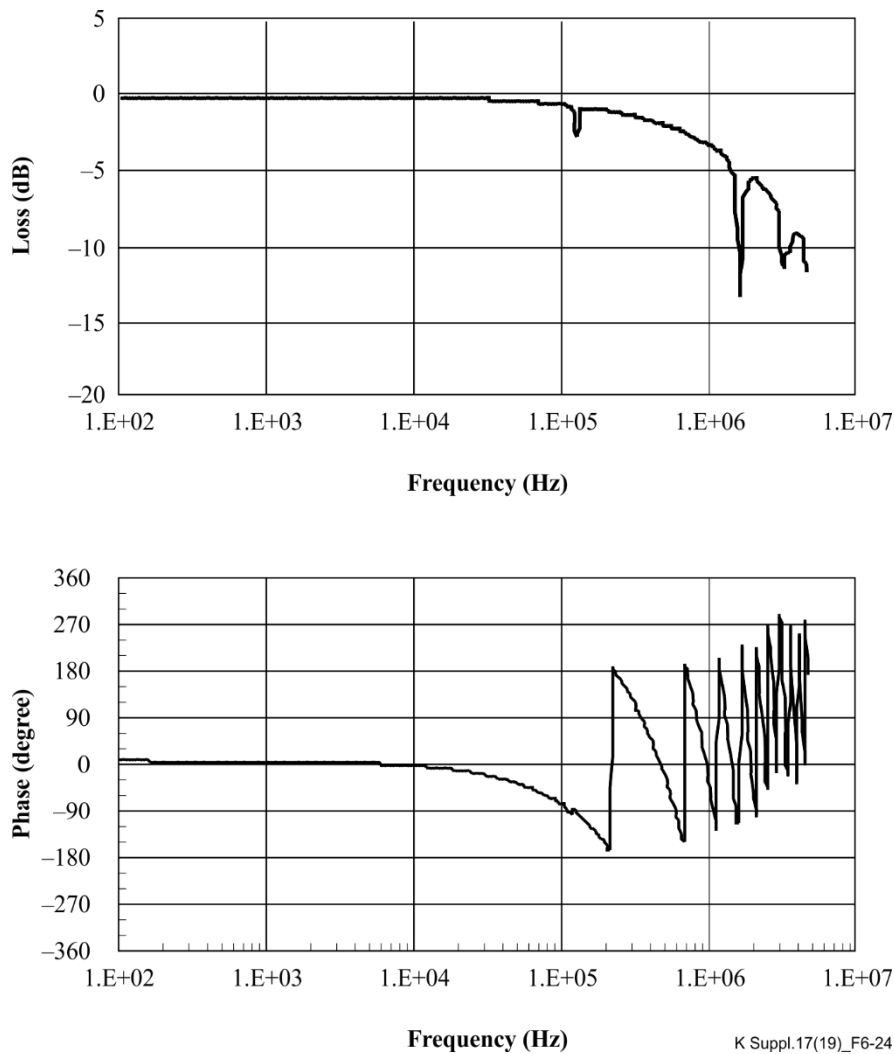**Figure 6-23 – Frequency characteristics of inductance**

Figure 6-24 – Frequency characteristics of transmission loss

6.6.2 Effect of inductance and resistance decoupling elements on digital circuits

Transmission characteristics were measured using an ISDN router and a VDSL modem. The test set-up for the ISDN is shown in Figure 6-25. This set-up is for a port to earth surge test, which is based on Figure A.5-1 of [ITU-T K.44]. The equipment that was used in this experiment is shown in Table 6-2. Tested combinations of L_{dcp} and R_{dcp}, and the results are summarized in Table 6-3. In all cases, the digital telephones and the PCs were connected.

The test set-up for the VDSL is shown in Figures 6-26 and 6-27. The specifications of the VDSL modem under tested are summarized in Table 6-4. The results for the different decoupling methods are shown in Table 6-5. It can be seen, for decoupling methods 4 and 5, that the throughput decreases slightly. In row 6 no decoupling element was used, only a 2 m length of Cat-5 cable, to show the throughput for a normal situation.
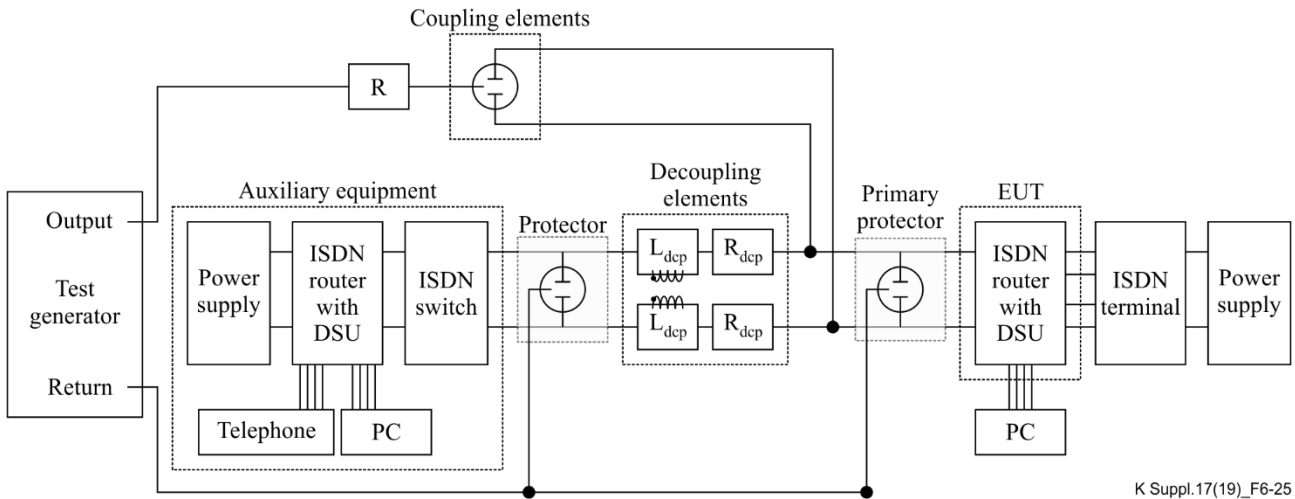
Figure 6-25 – Test set-up for integrated services digital network equipment

Table 6-2 – Integrated services digital network equipment

Item	Equipment
Digital telephone (EUT side)	S-1000 (NTT)
Digital telephone (AUX side)	DC-R2100 (NTT)
ISDN router (EUT)	MN128-SOHO (NTT-ME)
ISDN router (AUX side)	MN128-SOHO (NTT-ME)
ISDN switch	I64-4LINES and iNet-U2-LINES
Test generator	PSURGE 4.1 (HAEFELY)

Table 6-3 – Decoupling element and results

Test case	L_{dcp} (mH)	R_{dcp} (Ω)	Result
1	–	50	Good
2	–	100	Good
3	–	200	Good
4	20	–	Good
5	20	200	Good

Figure 6-26 – Test set-up for very high-speed digital subscriber line equipment

Table 6-4 – Specifications of very high speed digital subscriber line modem

Item	VDSL
Modulation	DMT
Communication	Full duplex (TDD)
Data rate	28.8 Mbit/s 51.2 Mbit/s/6.4 Mbit/s
Band allocation	1.5 Mbit/s or less, 64 kbit/s units 1.5 Mbit/s or more, 1 Mbit/s units
Transmission distance	300 m (28.8 Mbit/s) 300 m (51.2 Mbit/s/6.4 Mbit/s) 1 km (13 Mbit/s)
Error correction	Error correction for impulse noise, etc.
Splitters	Required

Table 6-5 – Decoupling element and results

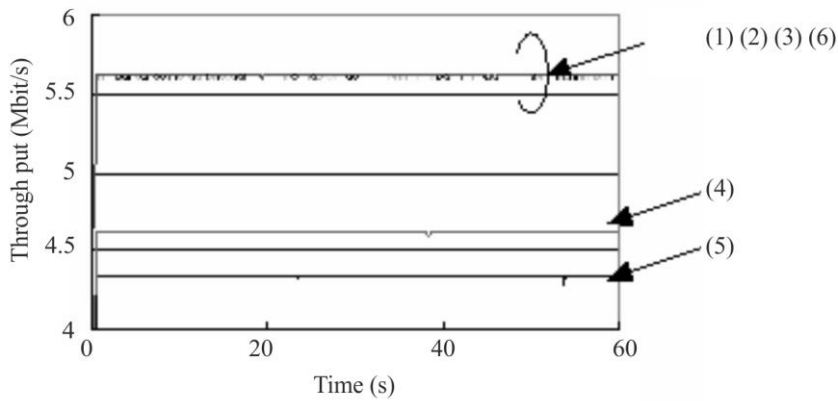| Test case	L_{dcp} (mH)	R_{dcp} (Ω)	Average throughput (Mbit/s)	
			Master side	**Slave side**
1	–	50	24	5.6
2	–	100	24	5.6
3	–	200	24	5.6
4	20	–	21	4.6
5	20	200	19	4.3
6	–	–	24	5.6

Figure 6-27 – Measurement results of throughput

6.7 Mains port testing

Confusion sometimes occurs over what tests are required, i.e., A to N and A/N to E, for various systems. In a mains distribution system with the neutral earthed at the customer premises, it may be thought unnecessary to perform A/N to earth tests. In systems where the neutral is not earthed, it may be thought that the A to N test should be performed with the generator floating. Both these cases are illustrated in Figure 6-28. In both cases, an A to N surge results in both a transverse or differential and port to earth surge in respect of the EUT and its secondary circuits. In the interests of repeatability

and to have the same test for different power systems, it is better to perform the transverse or differential test without a port to earth surge and the port to earth test without a transverse/differential surge. This is achieved using the test circuits given in Figures A.6.4-1 (for transverse or differential surges), A.6.4-2 (for port to earth surges) and A.6.4-3 (for port to port surges) of [ITU-T K.44].

Figure 6-28 – Effect of an A to N surge on equipment

a) Termination for IT distribution systems

b) Termination for TN-S and TT distribution systems

c) Termination for TN-C distribution systems

d) Termination for TN-C-S distribution systems

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Figure 6-29 – Terminations for mains ports

a) Termination and coupling to ground for IT distribution systems

b) Termination and coupling to ground for TN-S and TT distribution systems

c) Termination and coupling to ground for TN-C distribution systems

d) Termination and coupling to ground for TN-C-S distribution systems

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Figure 6-30 – Terminations and coupling to earth for mains ports

In the interests of global testing, it is recommended that Figure 6-29 a) be used as a termination for an untested mains port, and that Figure 6-30 b) be used to couple an untested mains port to earth.
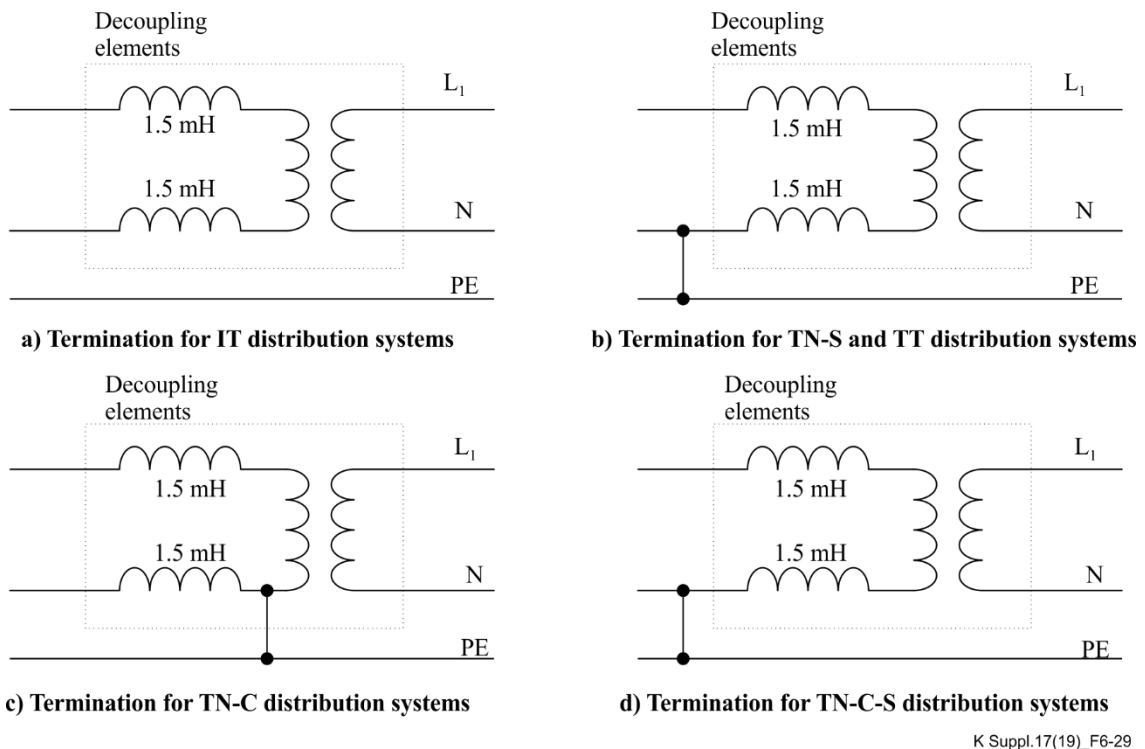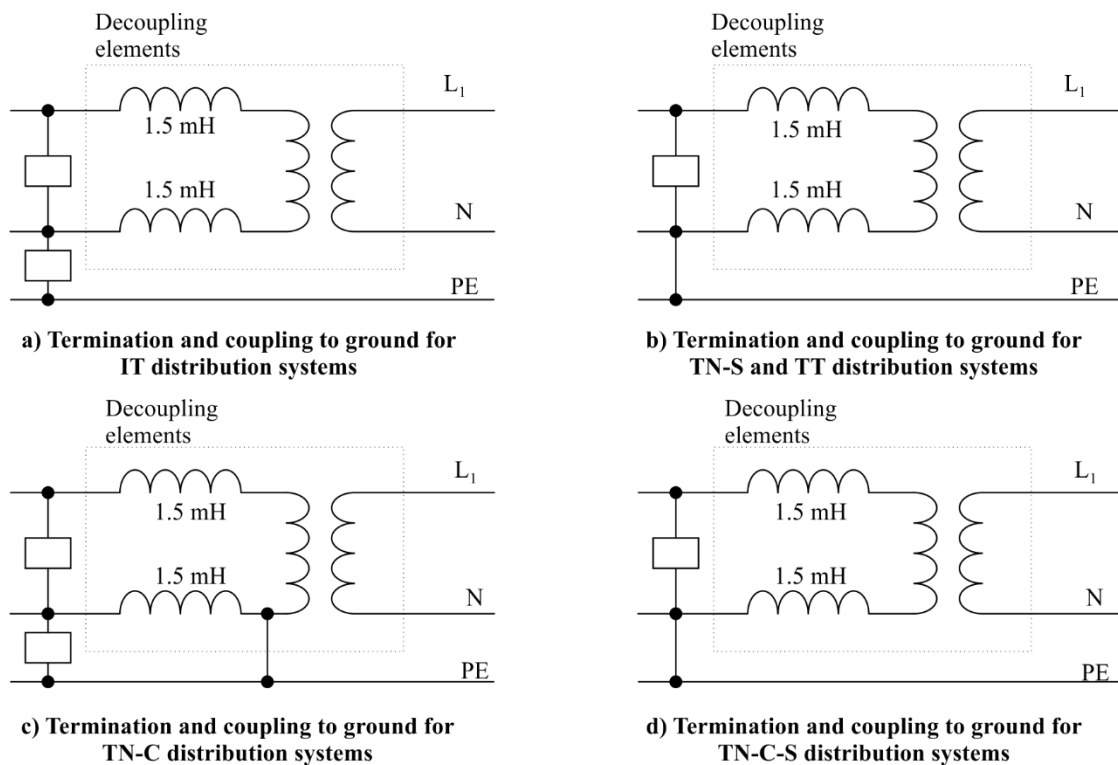
7 Range of lightning and power induction test levels

7.1 Lightning

7.1.1 Inherent test levels

The range of test voltages used in product Recommendations for the inherent resistibility test levels could be from 1.0 kV to 5.0 kV. Traditionally, a test voltage of 1.0 kV has been used in large telecommunication buildings. This is because the majority of surges will be less than 1.0 kV and it is relatively easy to install reliable primary protection on the MDF when required. A figure as high as 5.0 kV could be considered for CPE, as it is in a far less controlled environment and it is far more difficult to install GDTs.

7.1.2 Coordination test levels

The maximum test level for the coordination requirement has traditionally been 4.0 kV. However, recent measurements have shown that surge levels in excess of 7.0 kV do occur. An optional test level of up to 10.0 kV is allowed. The higher test level has a higher dU/dt. This results in a higher firing voltage of the primary protector and higher capacitive charging currents in the equipment.

7.2 Power induction test levels

7.2.1 Inherent test levels

Traditionally, the inherent test has been 0.2 A^2s for equipment in telecommunication centres and CPE. With the liberalization of customer premises, the use of primary protection is less certain and the inherent test level may need to be higher for CPE, e.g., 1.0 A^2s.

7.2.2 Inherent/coordination test levels

Traditionally, the level for the test with primary protection was 1.0 A^{2}s. An enhanced test level of 10 A^{2}s has been introduced to take into account that some countries have higher levels of power induction, maximum level of power induction into short lines (200 Ω) or the need for a high grade of service due to changing regulatory requirements.

The method of specifying the requirements for equipment may need to be different. [b-ITU-T K.20] specifies a $U_{c(max)}$ of 600 V through 600 Ω for 1 s. Measurements have shown that the range of time for which the fault current flows is from 0 to 3.2 s and that the current flowing in a telecommunication circuit can vary from 0 to 9 A$_{rms}$, see Figure 6-8. Tests on a resistor have shown that its I^{2}t rating decreases with increasing current for a constant I^{2}t. This shows that the inherent or coordination test has to be performed at the maximum current which occurs.

8 Relationship between [ITU-T K.44] and other product or product family Recommendations

[b-ITU-T K.20] is for equipment installed in a telecommunication centre. There is a proper earthing system and metal structure described in [b-ITU-T K.27], so the environment is not so exposed. However, due to the large number of telecommunication cables, the total current which flows into the building will be large.

[b-ITU-T K.21] is for equipment installed in customer premises. It assumes that good earthing and bonding practices according to [b-ITU-T K.66] have been followed. If bonding between the telecommunications and power services has not been implemented, damage to telecommunication equipment may occur. If damage does occur, solutions according to clauses 5 and II.6 of [ITU-T K.44] should be implemented.

[b-ITU-T K.45] is for equipment installed between the telecommunication centre and customer premises. The earthing system is not as good as that for a telecommunication centre, but the system is under the control of an operator. There is some merit in that the small structure allows ideal equipotential bonding.

Figure 8-1 shows an example of the location of the equipment and Recommendations to be applied. If the equipment is used in more than one location, it has to be tested according to all relevant Recommendations.
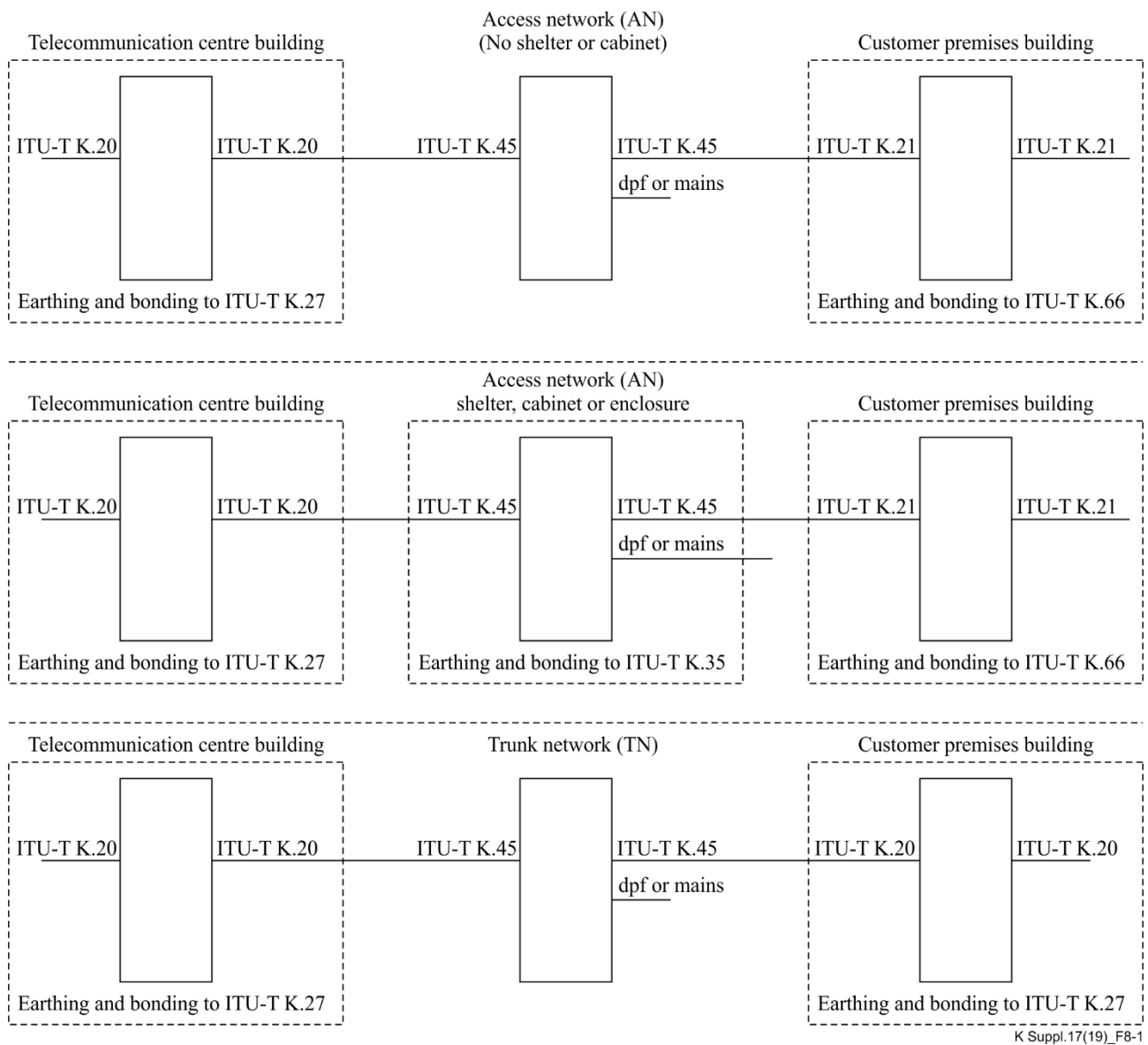
Figure 8-1 – Example configuration of a telecommunication network showing the border between a telecommunication centre, the access or trunk network and customer premises

Bibliography

[b-ITU-T K.20]   Recommendation ITU-T K.20 (2019), *Resistibility of telecommunication equipment installed in a telecommunication centre to overvoltages and overcurrents*.

[b-ITU-T K.21]   Recommendation ITU-T K.21 (2019), *Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents*.

[b-ITU-T K.27]   Recommendation ITU-T K.27 (2015), *Bonding configurations and earthing inside a telecommunication building*.

[b-ITU-T K.45]   Recommendation ITU-T K.45 (2018), *Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents*.

[b-ITU-T K.66]   Recommendation ITU-T K.66 (2011), *Protection of customer premises from overvoltages*.

[b-ITU-T K.82]   Recommendation ITU-T K.82 (2010), *Characteristics and ratings of solid-state, self-restoring overcurrent protectors for the protection of telecommunications installations*.

[b-IEC 61000-4-5]   IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*.

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