INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

K.64

(02/2004)

SERIES K: PROTECTION AGAINST INTERFERENCE

Safe working practices for outside equipment installed in particular environments

ITU-T Recommendation K.64

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Safe working practices for outside equipment installed in particular environments

Summary

This Recommendation describes working practices for service personnel to help service personnel work safely at telecommunication installations in three specific environments.

The specific environments covered in this Recommendation are characterized by wet conditions or close proximity to exposed metallic parts.

The working practices apply to telecommunications plant with voltage levels higher than the limits defined for analogue PSTN circuits, such as RFT-C or RFT-V circuits.

Source

ITU-T Recommendation K.64 was approved on 29 February 2004 by ITU-T Study Group 5 (2001-2004) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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

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

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

NOTE

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

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INTELLECTUAL PROPERTY RIGHTS

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

Introduction

Network Operators, in their telecommunication infrastructure, use equipment that is remotely powered by symmetrical or coaxial pair cables. The voltages and currents that power these systems differ among them, and comply with the limit values defined in standards IEC 60950-1 and IEC 60950-21 for symmetrical pair cables and in standard IEC 60728-11 for coaxial cables. The limits in these standards have been defined to allow service personnel to work safely on these lines without de-energizing the circuits.

Nevertheless, there are telecommunication environments that necessitate additional precautions to enable service personnel to work safely on circuits that are usually considered safe to touch. These environments are characterized as wet conditions, sometimes associated with standing water. This Recommendation lists three practical situations where additional precautions are needed and defines how the service personnel should perform work to reduce risk associated with these situations.

Specific applications, local conditions or regulations may give rise to a need for additional safeguards or modifications to practices presented in this Recommendation.

ITU-T Recommendation K.64

Safe working practices for outside equipment installed in particular environments

1 Scope

The scope of this Recommendation is to provide working procedures for maintenance activities in specific environments for telecommunications plant with voltage levels higher than the limits defined for analogue PSTN circuits. The specific environments covered in this Recommendation are characterized by wet conditions or close proximity to exposed metallic parts.

2 References

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

[1] IEC 60950-1 (2001-10), *Information technology equipment – Safety – Part 1: General requirements*.

[2] ITU-T Directives (Vol. VI, 1989), *Danger and disturbance*.

[3] ITU-T Directives (Vol. VII, 1989), *Protective measures and safety precautions*.

[4] IEC/TR2 60479-1 (1994-09), *Effects of current on human beings and livestock – Part 1: General aspects*.

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

[6] ITU-T Recommendation K.51 (2000), *Safety criteria for telecommunication equipment*.

[7] IEC 60728-11 (WIP), *Cable networks for television signals, sound signals and interactive services – Part 11: Safety requirements*.

[8] IEC 60950-21 (2002-12), *Information technology equipment – Safety – Part 21: Remote power feeding*.

3 Definitions

This Recommendation defines the following terms:

3.1 CATV circuit: An interface circuit for a CABLE DISTRIBUTION SYSTEM intended for transmission of video, data and/or audio signals between separate buildings or between outdoor antennas and buildings.

NOTE – CATV circuits remotely powered, i.e., circuits on feeder between the Optical Node Unit and the last line amplifier, are only considered in this Recommendation.

3.2 dry conditions: An environmental condition in which the resistance of the skin and to the body is not reduced with respect to the value defined in IEC 60479-1.

3.3 environment classification: The environments considered by this Recommendation are classified as follows:

- Environment Type 1: environment with the floor in wet conditions, sometimes with standing water (for example, manholes, vaults, trenches);
- Environment Type 2: environment with wet walls and confined working space (for example, vaults) such that the wet wall may be in contact with the person's body and producing (in the case of hand contact with an energized part) a current path different to the hand-to-feet current path;
- Environment Type 3: environment with confined working space and existing extraneous metallic parts (for example, facilities of other services); during the operations, large area of the metallic parts (e.g., metallic tower for radio link) are in continuous contact with the body.

3.4 insulated tool: A tool, such as a screwdriver, scissor or pliers, having an insulated handle, that may be used by service personnel during his operations on telecommunications equipment or cable.

3.5 analogue PSTN circuit: A TNV circuit (see 3.9) operating at voltages less than or equal to 90 V d.c. with cadenced ringing signals complying with IEC 60950-1.

3.6 RFT-C circuit: A Remote feeding telecommunication circuit, that is so designed and protected that under normal operating conditions and single fault conditions, the currents in the circuit do not exceed defined values.

NOTE – The current limit values under normal operating and single fault conditions are specified in ITU-T Rec. K.50 or IEC 60950-21.

3.7 RFT-V circuit: A Remote feeding telecommunication circuit that is so designed and protected that under normal operating conditions and single fault conditions, the voltages are limited and the accessible area of contact is limited.

NOTE – The voltage limit values under normal operating and single fault conditions are specified in ITU-T Rec. K.50 or IEC 60950-21.

3.8 service personnel: A person having appropriate technical training and experience necessary to be aware of hazards, to which that person may be exposed in performing a task, and of measures to minimize the risks to that person or other persons.

3.9 TNV circuit: A circuit in the equipment to which the accessible area of contact is limited and that is so designed and protected that, under normal operating conditions and single fault conditions, the voltages do not exceed specified limit values.

3.10 user: Any person other than service personnel.

3.11 wet condition: An environmental condition in which the resistance of the skin and to the body is reduced with respect to the value defined in IEC 60479-1.

3.12 vault: An underground chamber (manhole, pit, exchange or high rise building cable entry) or above ground pedestal or cabinet used to accommodate communication equipment, such as, joint closures, housings and/or electronic equipment installed in the external plant environment.

4 Abbreviations

This Recommendation uses the following abbreviations:

CATV Cable TV

CCP Cross-Connection Point

DC Direct Current

MDF	Main Distribution Frame
PSTN	Public Switched Telephone Network
RFT-C	Remote Feeding Telecommunication – Current circuit
RFT-V	Remote Feeding Telecommunication – Voltage circuit
rms	Root Mean Square
SELV	Safety Extra Low Voltage
TLC	Telecommunication
TNV	Telecommunication Network Voltage

5 Telecommunication particular workplaces

Safety standards recognize that voltage levels defined as safe to touch in normal conditions may present a hazard to service personnel in damp conditions. For example, it is recognized that the same SELV circuit limits may present a risk of electric shock for a person when such circuits are used in a wet environment; for this reason the voltage limit for parts touchable by a person is equal to the half value of the limit applicable in the environment with dry conditions.

Obviously, it is not possible to reduce the voltages usually present on a telecommunications line to lower values in order to have the same conditions for a wet environment and contact with service personnel. In such cases, recognizing the presence of potentially harmful energy sources, the behaviour of the service personnel becomes an effective means to prevent injury. Therefore, there is the need to follow safe working practices when equipment maintenance is necessary and a dry environment is not possible. This approach is possible because the service personnel are skilled and trained.

An example of such work is the maintenance activities inside a manhole or, in general, in a vault where the presence of water at the bottom is as likely as the infiltration of water on the internal walls. Sometimes, the confined space of the workplace does not make it easy for maintenance of the equipment and increases the likelihood that the current path through the person's body will be different from the hand-to-feet current path. Lastly, service personnel may accidentally make an adverse, large-area contact with energized conductors. This could happen, for instance, if one hand holds a tool fastened to the energized conductor while the other hand, or another body part, is in full contact with an earthed conductor.

Summarizing, there are three particular environments that may present safety hazards to service personnel who operates on TLC plant:

1) Environment Type 1: wet conditions (see 3.3);
2) Environment Type 2: confined working space in wet conditions (see 3.3);
3) Environment Type 3: confined working space contacting extraneous metallic parts (see 3.3).

To reduce the risk of electric shock associated with the maintenance activities performed in such an environment, service personnel shall follow simple and effective working practices, as described in clause 7.

6 Voltage levels on TLC installations

IEC 60950-1 allows voltage levels, not higher than 70.7 V (peak) or 120 V d.c., on symmetrical pair cables of telecommunication networks. TNV circuits, accessible to skilled personnel only, are safe for an ordinary environment (dry conditions) but in wet conditions the contact with TNV circuits at voltages greater than analogue PSTN voltages (see 3.5) may be dangerous for service personnel due to a reduction of the contact impedance.

The voltage levels used in a coaxial cable distribution network are defined in IEC 60728-11. Voltage levels between the inner and outer conductor of up to 65 Vrms, 120 V d.c. are allowed. It must be considered that such voltage levels shall be completely inaccessible to the user and the service personnel may access these voltages only after removing, with a tool, the equipment cover.

IEC 60950-21 has introduced the Remote Feeding Telecommunication Circuits limited in Current (RFT-C) or in voltage (RFT-V). Both circuits are suitable for barehanded contact by service personnel in powered state in line with ITU-T Rec. K.50.

Table 1 summarizes the voltage levels that may be present on a telecommunication line under normal conditions for different types of circuit in the network [1], [5], [7] and [8]. These voltage levels are based on the assumption that the surface contact area is not greater than 1 cm^2 in order to limit body impedance in the hand-to-feet path to > 5 kΩ.

Table 1/K.64 – Voltages on TLC line in normal conditions for different types of circuits in the equipment powering the network

Type of circuit	V d.c. max [V]	V a.c. max [V]
TNV	120	70.7 (peak value)
RFT-C	± 400 (Note 1)	n.a.
RFT-V	± 140 (Note 2)	n.a.
CATV	120	65 (rms)
NOTE 1 – If the voltage rating of the wiring of the telecommunication network is not specified. If it is specified, the supply voltage shall be limited to this value or to a maximum value of 1500 V (see Annex B/K.50). NOTE 2 – Or ± 200 V if the short circuit current is limited to 10 mA d.c (see Annex A/K.50).		

Essentially the current flowing through the body determines human responses to electrical stimuli. Voltage is important because, together with the body impedance, it determines the current through the body.

The previous voltage/currents limits have been calculated using the 'let-go' limit. This defines the threshold at which inability to release the energized conductor occurs. In the case of limited voltage circuits, e.g., TNV and RFT-V circuits, the voltage limits have been defined using a body impedance of 5 kΩ. This introduces a margin of safety into the limit in case a current path through a body is created because higher values of body impedance may be encountered in practice, as indicated by IEC 60479-1 (small contact surface area).

Working practices performed on live conductors affect the likelihood that a possible physiological response may occur. The likelihood of specific response of the body occurring at a specific voltage level depends on the precautions adopted whilst working on those live parts. These precautions may be very simple for lower voltages, but can include the disconnection of the power feeding on the cable or on the equipment before working.

The safety precautions described below allow service personnel to work safely in specific environments defined in this Recommendation.

NOTE – The possible effects of induced voltages on telecommunication line are under study.

7 Work practices on TLC plant in particular environments

Work on telecommunication installations under normal conditions as well as in specific environments considered in this Recommendations (Environments Type 1, 2 or 3) shall only be performed by skilled service personnel following well-defined safe working procedures.

This Recommendation requires, first of all, the classification of the telecommunication installation where it is necessary to work; practically the installations with voltages from TNV, RFT-C, RFT-V or coaxial cable circuits have to be indicated. Before starting the work, this Recommendation requires that service personnel assess the risk by determining the voltage classification in the telecommunication facilities (e.g., consulting records/maps (plans) of the TLC facilities, in which information on the type of service is reported).

For conductors with voltages higher than the analogue PSTN service, labels or insulated markers (e.g., coloured plastic collets) should be installed at the MDF and at accessible cross-connection points (CCP) along the route that clearly indicates both the service and the voltage. In these cases, the safety precautions described in 7.1 and 7.2 (Figure 1) shall be followed.

7.1 Switching off power supply

Electrical works on TLC installations in environments Type 1, 2 or 3 should be performed, preferentially, with the power supply switched off or by using insulating or disconnect or shorting devices at the MDF or other suitable CCPs on the conductors carrying the potentially hazardous voltage levels within the scope of this Recommendation.

Where practicable, a temporary notice should also be placed at the MDF that clearly indicates the necessity to leave in place the insulating or disconnect devices or switch position because works are in progress on the line.

Nevertheless, the warning shall be considered sufficient only if the disabling devices are used in places where the access is limited to service personnel only; otherwise, it is required to lock the disabling devices in their "Off" position.

Once the work has been completed, the power supply may be reconnected only after the service personnel have made the installation safe.

At the MDF, those conductors carrying voltage levels from RFT-V or RFT-C circuits should be labelled. Unintentional contact between conductors from different power feeding circuits, even of the same type, should be avoided, e.g., by providing insulating shielding covers.

Prior to work starting, service personnel are required to verify, through use of an appropriate measuring instrument, the absence of voltages exceeding analogue PSTN limits (see 3.5) on all conductors where it is necessary to operate.

7.2 Practices to be used when working on live telecommunication circuits

Where it is not practicable to disconnect the power feed to those parts that may be touched bare-handed by service personnel under the specified environment, tools with insulated handles or by other effective insulated protection devices (e.g., insulated gloves and/or in Type 1 environment, rubber boots) should be used.

For the different Environment Types defined in this Recommendation, it is necessary to adopt the following safety precautions[1]:

– Environment Type 1: if voltages on TNV or RFT-V circuits with no current limitation are higher than 105 V d.c., it is necessary to use insulated connectors or tools with insulated handles to avoid a bare-hand contact with conductors and/or rubber insulating boots to prevent moisture contact with the feet/legs.

– Environment Type 2 and 3: if voltages on TNV or RFT-V circuits with no current limitation are higher than 90 V d.c., it is necessary to use insulated connectors or tools with insulated handles, insulated boots or insulated gloves.

  Environment Type 2 and 3: if voltages on coaxial cables are higher than 60 Vrms, it is necessary to use insulated connectors or tools with insulated handles.

When work is performed on live parts, it is essential that likely earth faults or leakage currents (see B.3/K.50), in particular with floating power systems that may originate dangerous touch currents (RFT-C circuits), be detected by measurement and the low impedance to earth fault of the one line conductor be removed before beginning work.

These safety precautions for live working on different types of environment are summarized in Table 2.

During work close to other telecommunication live parts different from PSTN circuits, if service personnel may not be able to use special protection devices, the worker is careful to maintain his hands sufficiently far away from those live parts.

Table 2/K.64 – Safety precautions for live working in different types of environment

Environment	TNV circuit	RFT-C circuit	RFT-V circuit with no current limitation	CATV circuit
Environment type 1: wet conditions	If above 105 V d.c., use insulated connectors or tool handles.	Touch only one conductor and check for earth faults on the line.	If above 105 V d.c., use insulated connectors or tool handles.	No specific precautions given.
Environment type 2: confined working space in wet conditions	If above 90 V d.c., use insulated connectors or tool handles.	Touch only one conductor and check for earth faults on the line.	If above 90 V d.c., use insulated connectors or tool handles, insulated gloves or boots.	If voltages above 60 Vrms, use insulated connectors or tool handles.
Environment type 3: confined working space contacting extraneous metallic parts	If above 90 V d.c., use insulated connectors or tool handles.	Touch only one conductor and check for earth faults on the line.	If above 90 V d.c., use insulated connectors or tool handles, insulated gloves or boots.	If voltages above 60 Vrms, use insulated connectors or tool handles.

[1] The indicated values are calculated in Appendix I.

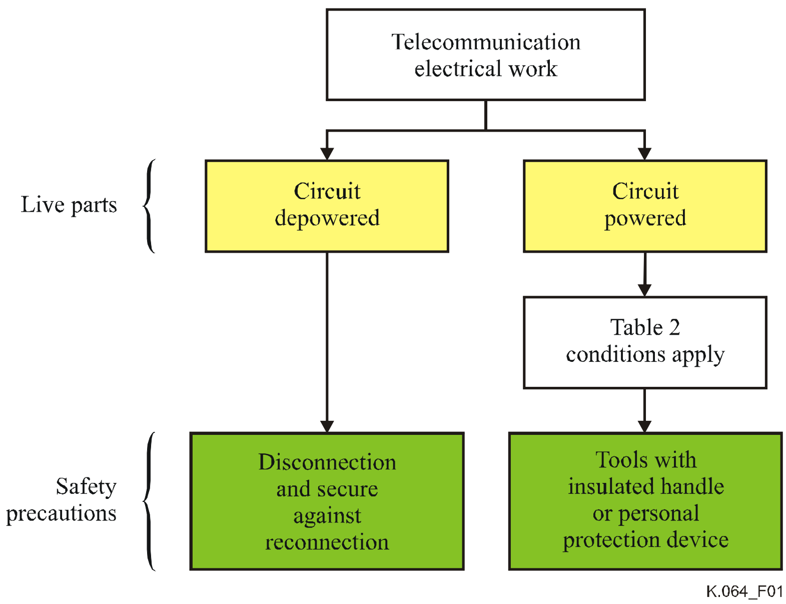


Figure 1/K.64 – Scheme for safety procedures in particular environment (see 3.3)

8 Work on telecommunication installations at risk of electric shock

Usually, work performed on a telecommunication plant may consist of one of the following activities:

– maintenance or replacement of equipment;

– operations on cables.

NOTE – This Recommendation is concerned only with the above two points because it is considered that prior to the plant's first activation, it is switched off and so is not dangerous in the meaning of this Recommendation.

8.1 Work on equipment or devices (terminal box, etc.)

Equipment installed in environments at risk of electric shock shall have a warning mark clearly visible on its enclosure to remind service personnel of the need to use the appropriate safety procedures.

In an environment like a manhole, installation and siting of equipment should take into account the need to perform maintenance activities. Where possible, consideration should also be given in the installation and siting of equipment to allow ease of operations in the workplace. One example of this is the use of cables long enough to allow equipment within the manhole to be either:

- temporarily removed from the manhole entirely and placed on the road surface;
- raised from the floor of the manhole to a level at which maintenance may be performed from the outside.

Unless the road surface is wet, the operation in these conditions is comparable to that performed in an ordinary environment.

When it is necessary to operate in an environment such as a vault, then, considering the likely limited freedom of movement, the working procedure must be subordinated to the nature of the operation.

For such a purpose, as far as maintenance activities on line or terminal equipment are concerned, it is possible to distinguish the following cases:

1) Electrical measurements: it is required that the measurement instruments and their accessories have an insulation level adequate to the expected voltages present on the telecommunication line;
2) Maintenance by removal or insertion of components directly extractable;
3) Maintenance with action by hand directly on components without accessible parts at dangerous voltages;
4) Maintenance with action by hand on components having accessible parts at dangerous voltages.

Only when the operation should be performed on accessible parts of live equipment is it necessary to use tools with insulated handle. In other cases, service personnel will not experience harmful effects and so bare-hand operation is possible.

Replacement of equipment shall be performed only after the power supply has been switched off.

8.2 Works on cables

Generally, work on a cable can be safely carried out if the cable sheath is not open or, after its opening, it is not possible to touch the internal conductors with remote power feeding voltages higher than analogue PSTN limits.

The external conductor of a coaxial cable or the plastic insulation of pair cable conductors shall not be damaged during the work.

During normal activities performed on cables, e.g., splice making, contact may occur with the entire span of the hand or even hand to hand. Such possibilities shall be avoided. Therefore, splicing techniques that do not remove the insulation of the conductors are preferred.

Two kinds of splicing are possible on cables:

1) making a new splice involving all the conductors of the cable;
2) remaking a splice involving some conductors of the cable.

The first case may occur, e.g., when a cable has been cut in the field, and since the telephone service is down, it may be convenient to disconnect the power supply on all conductors with voltage levels higher than analogue limits (PSTN services) to protect service personnel making the splice in an environment at risk of electric shock.

In the second case, two methods may be used:

1) Identify the pairs in the splice with voltages exceeding analogue PSTN limits using instruments like "pair-finders" or by traditional methods that require service personnel to proceed by trial and error, contacting the conductors one by one in order to identify them at the exchange on the network side. Label them to avoid unwanted contacts. This may be the easiest method with paper insulated conductors.
2) Use insulated tools to avoid conductive paths to earth. This may be the most practicable method for plastic insulated conductors.

The conductors with voltage levels higher than the analogue limits (PSTN services) shall be interrupted at the MDF/CCP with suitable insulators/disconnectors or shorting devices unless splicing is performed without the likelihood of skin contact with bare conductors by using suitable personal protective devices and practices described in 7.2.

As for equipment, the service personnel shall ensure, first of all, that cable conductors are not powered. Operation on the cable prior to verification that the power remote feeding has been switched off shall be performed using insulated tools.

Appendix I

Rationale of safe voltage limit values for workplace at major risk of electric shock

This appendix describes rationale leading to safe voltage limit values shown in Table 2 for human safety while operating on TNV, RFT-V and CATV circuits in workplace at major risk of electric shock.

Calculation is according to IEC 60479-1 determining voltage and current values that, in the case of human body contacts with active parts of telecommunication plant, do not generate dangerous situations for trained personnel.

I.1 Operating cases

With reference to environment type classification for electric shock risk, defined in 3.3, different operating conditions, that could determine different effects on the human body, have been identified.

They depend substantially on the contact type of body with telecommunication plant and ground, and site environment conditions.

The body parts which can contact the telecommunication plant and ground are:

- hands;
- back;
- seat;
- feet.

I.2 Calculation assumption

Calculations have to determine the contact voltage limit originated by touching telecommunication plant that, based on human body impedance value in contact path (Z), generates no dangerous current for people.

For this, refer to IEC 60479-1 that considers this impedance Z constituted by:

$$Z = Z_b + Z_c$$

where:

Z_b is a partition of human body impedance, function of surface contact and touch voltage, developing through the current path considered

Z_c is the touch ground impedance

Figure I.1 shows human body impedance, function of surface contact and touch voltage Z_T, through hand-to-hand path.

To get Z_b value is needed to calculate human body impedance partition, in the path interested by the contact, with respect to such impedance Z_T.

Such partition can be obtained by Figure I.2.

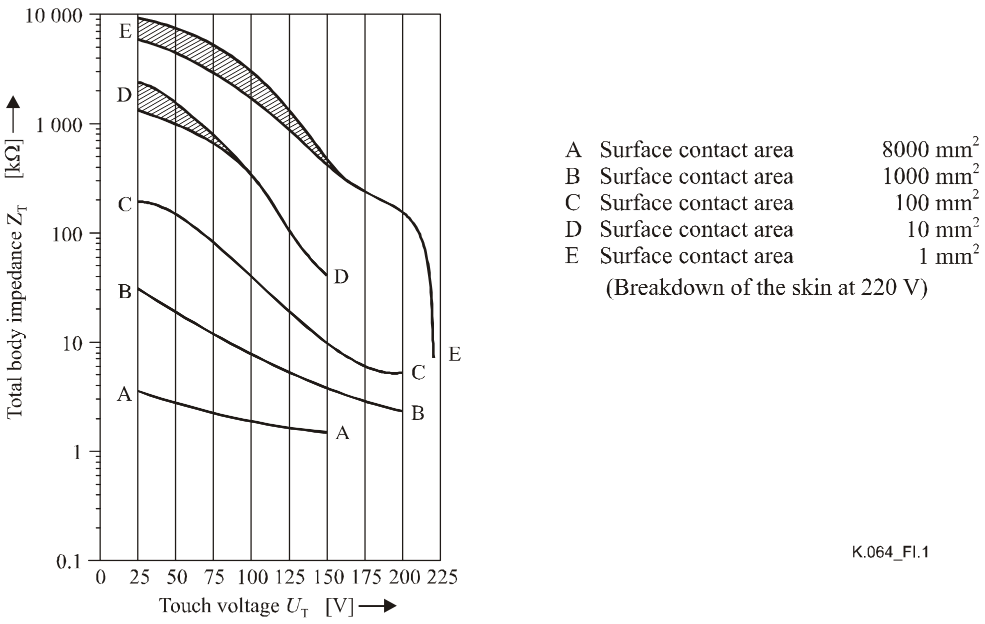
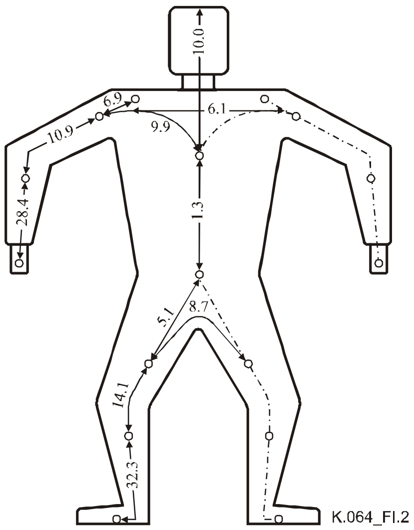


Figure I.1/K.64 – Human body impedance for hand-to-hand path



The numbers indicate the percentage of the internal impedance of the human body for the part of the body concerned, in relation to the hand-to-foot path.

NOTE 1 – In order to calculate the total body impedance Z_T for a given current path, the internal impedances for all parts of the body of the current path have to be added as well as the impedances of the skin of the contact areas.

NOTE 2 – The internal impedance from one hand to both feet is approximately 75%, the impedance from both hands to both feet 50% and the impedance from both hands to the trunk of the body 25% of the impedance hand-to-hand or hand-to-foot.

Figure I.2/K.64 – Percentage of the human body internal impedance in relation to the hand-to-foot path

Therefore:

$$Z_b = k \times Z_T$$

where k is the sum of percentages met in the considered path.

Although, according to IEC 60950-1, the surface contact to be considered is 100 mm^2 (fingertip dimension), this calculation should take into consideration the possibility that the operator, while using insulated tools, touch accidentally active telecommunication parts with the whole finger. Therefore, this surface is assumed to be 1000 mm^2, and consequently curve B of Figure I.1 should be taken into account.

Regarding body impedance contact with ground Z_c, it is assumed that:

- Floor and walls are always wet or damp and their impedance is assumed no greater than 200 Ω;
- Shoes wet or damp impedance is 1000 Ω [ref. HD637 CENELEC standard];
- Metallic parts impedance is assumed 0 Ω.

Therefore, cases to be analysed are those shown in Table I.1 considering negligible the difference between back and seat path (1.3%).

Table I.1/K.64 – Analysis cases

Case	Environment type	Contact path	Condition of shoes	Impedance contact with floor, wall or metallic parts	% impedance of human body with respect to the path [K]
1	1	hand-feet	wet or damp	1200 Ω	75
2		hands-feet			50
3		hand-foot			100
4	2	hand-hand		200 Ω	100
5		hand-seat			50
6		hands-seat			25
7	3	hand-hand		0 Ω	100
8		hand-seat			50
9		hands-seat			25

I.3 Limit current calculation

The level of danger of current flowing through human body is related to its intensity and its duration.

Figure I.3 shows the zone limits for different physiological effects for the human body and their description related to alternating current.

Figure I.4 shows the zone limits for different physiological effects for the human body and their description related to direct current.

Such current values can change depending on different current paths in the human body; the factor taking into account this fact is the so-called "heart-current factor" F, whose value is evidenced in Table I.2.

Therefore:

$$I_h = \frac{I_{ref}}{F}$$

where:

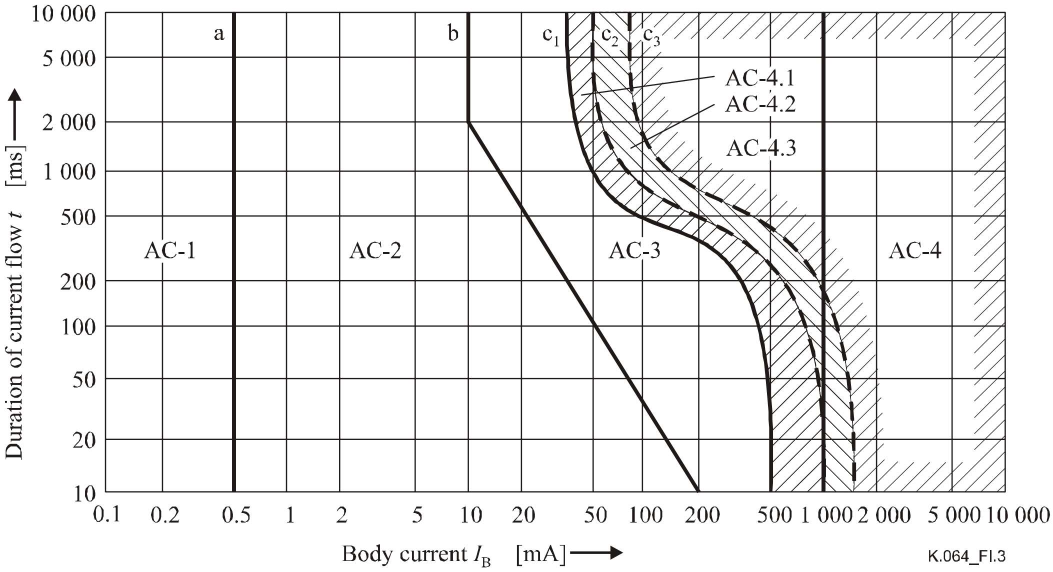
I_{ref} is the reference current in Figures I.3 and I.4

I_h is the current for different paths indicated in Table I.2

In case of similar paths, it has to be considered the most precautionary F value.

In Table I.3 are evidenced limit values for a.c. and d.c. with respect to "b" curve.

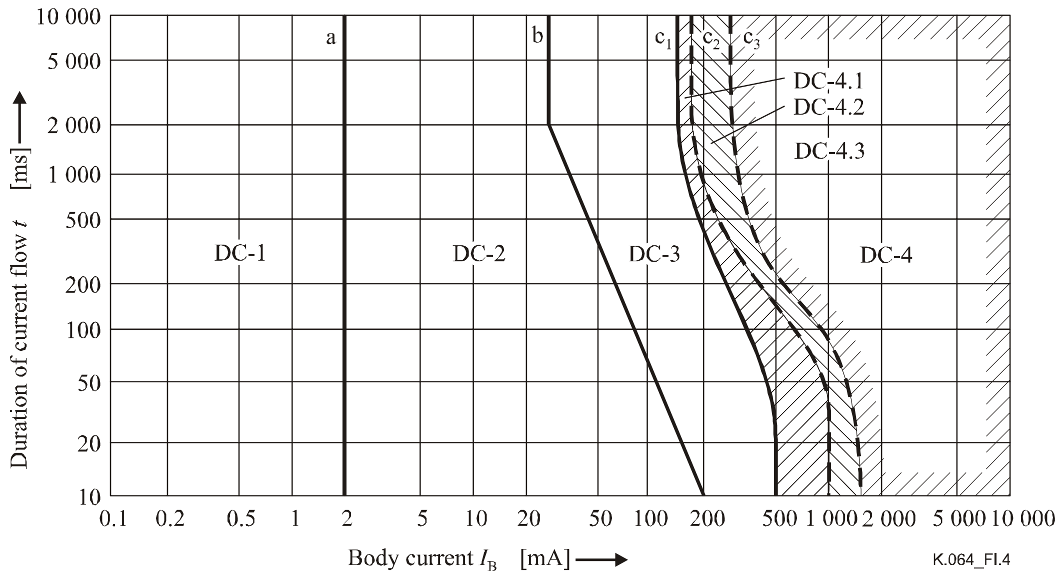
In Table I.4 are evidenced limit values for a.c. and d.c. with respect to "c_1" curve.



Zone descriptions

Zone designation	Zone limits	Physiological effects
AC-1	Up to 0.5 mA line a	Usually no reaction.
AC-2	0.5 mA up to line b (Note)	Usually no harmful physiological effects.
AC-3	Line b up to curve c_1	Usually no organic damage to be expected. Likelihood of cramp like muscular contractions and difficulty in breathing for durations of current-flow longer than 2 s. Reversible disturbances of formation and conduction of impulses in the heart, including a trial fibrillation and transient cardiac arrest without ventricular fibrillation increasing with current magnitude and time.
AC-4	Above curve c_1	Increasing with magnitude and time, dangerous pathophysiological effects such as cardiac arrest, breathing arrest and severe burns may occur in addition to the effects of zone 3.
AC-4.1	$c_1 - c_2$	Probability of ventricular fibrillation increasing up to about 5%.
AC-4.2	$c_2 - c_3$	Probability of ventricular fibrillation up to about 50%.
AC-4.3	Beyond curve c_3	Probability of ventricular fibrillation above 50%.
NOTE – For durations of current-flow below 10 ms, the limit for the body current for line b remains constant at a value of 200 mA.		

Figure I.3/K.64 – Physiological effects of alternating current on human body



Zone descriptions

Zone designation	Zone limits	Physiological effects
DC-1	Up to 2 mA line a	Usually no reaction. Slight pricking pain when switching on or off.
DC-2	2 mA up to line b (Note)	Usually no harmful physiological effects.
DC-3	Line b up to curve c_1	Usually no organic damage to be expected. Increasing with current magnitude and time, reversible disturbances of formation and conduction of impulses in the heart may occur.
DC-4	Above curve c_1	Increasing with current magnitude and time, dangerous pathophysiological effects for example, severe burns, are to be expected in addition to the effects of zone 3.
DC-4.1	$c_1 – c_2$	Probability of ventricular fibrillation increasing up to about 5%.
DC-4.2	$c_2 – c_3$	Probability of ventricular fibrillation up to about 50%.
DC-4.3	Beyond curve c_3	Probability of ventricular fibrillation above 50%.
NOTE – For durations of current-flow below 10 ms, the limit for the body current for line b remains constant at a value of 200 mA.		

Figure I.4/K.64 – Physiological effects of direct current on human body

Table I.2/K.64 – Heart-current factor

Current path	Heart-current factor *F*
Left hand to left foot, right foot or both feet	1.0
Both hands to both feet	1.0
Left hand to right hand	0.4
Right hand to left foot, right foot or to both feet	0.8
Back to right hand	0.3
Back to left hand	0.7
Chest to right hand	1.3
Chest to left hand	1.5
Seat to left hand, right hand or to both hands	0.7

Table I.3/K.64 – a.c. and d.c. limit values with respect to b curve

Case	Environment type	Path contact	Condition of shoes	Impedance contact with floor, wall or metallic parts [Ω]	% impedance of human body with respect to the path [k]	Heart-current factor F	Current reference a.c. for 'b' curve [mA]	Limit current a.c. for 'b' curve [mA]	Current reference d.c. for 'b' curve [mA]	Limit current d.c. for 'b' curve [mA]
1	1	hand-feet	wet or damp	1200	75	1.0	10.0	10.00	30.0	30.00
2		hands-feet			50					
3		hand-foot			100					
4	2	hand-hand		200	100	0.4		25.00		75.00
5		hand-seat			50	0.7		14.29		42.86
6		hands-seat			25					
7	3	hand-hand		0	100	0.4		25.00		75.00
8		hand-seat			50	0.7		14.29		42.86
9		hands-seat			25					

Table I.4/K.64 – a.c. and d.c. limit values with respect to c_1 curve

Case	Environment type	Path contact	Condition of shoes	Impedance contact with floor, wall or metallic parts [Ω]	% impedance of human body with respect to the path [k]	Heart-current factor F	Current reference a.c. for c_1 curve [mA]	Limit current a.c. for c_1 curve [mA]	Current reference d.c. for c_1 curve [mA]	Limit current d.c. for c_1 curve [mA]
1	1	hand-feet	wet or damp	1200	75	1.0	40.0	40.00	150.0	150.00
2		hands-feet			50					
3		hand-foot			100					
4	2	hand-hand		200	100	0.4		100.00		375.00
5		hand-seat			50	0.7		57.14		214.29
6		hands-seat			25					
7	3	hand-hand		0	100	0.4		100.00		375.00
8		hand-seat			50	0.7		57.14		214.29
9		hands-seat			25					

I.4 Voltage limit calculation

Voltage limits to be calculated, with respect to identified cases, correspond to the values generating the body impedances in Figure I.1 whose current flowing through the contact path has to be less than the limits shown in Tables I.3 and I.4.

Such calculations are summarized in Table I.5 where voltage value ranges are shown to identify the voltage corresponding to current limit value with respect to "b" curve and to "c_1" curve.

Therefore, it is possible to deduce the following conclusions:

- For Environment type 1, there are no critical cases for a.c. voltage because there is no value less than 65 V a.c.; regarding d.c. voltage, the most critical case is the 2nd one because it presents the smallest range of voltage values with respect to the other one having less than 140 V d.c.
- For environment type 2 and 3, the most critical cases are the 6th and the 9th regarding to a.c. voltage and to d.c. voltage because they present the smallest range of voltage values with respect to the other ones having less than 65 V a.c. and 140 V d.c., respectively.

Via mathematical analysis of the values reported in Table I.5, it is possible to associate the limit current value to the relative voltage and define the following critical values:

- Environment type 1 (Case 2): 105 V d.c.
- Environment type 2 and 3 (Cases 6 and 9): 90 V d.c., 60 V c.a.

Table I.5/K.64 – Corresponding voltage limits for "b" and "c_1" curves

Case	Environment type	Condition of shoes	Path contact		25	50	75	100	125	150	175	200	Limit current a.c. for 'b'curve [mA]	Voltage range corresponding to limit current a.c. [V]	Limit current d.c. for 'b' curve [mA]	Voltage range corresponding to limit current d.c. [V]	Limit current a.c. for 'c_1' curve [mA]	Voltage range corresponding to limit current a.c. [V]	Limit current d.c. for 'c_1' curve [mA]	Voltage range corresponding to limit current d.c. [V]
Voltage contact [Volt]					**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**								
Impedance of human body with respect to surface contact and voltage contact [ohm]					**32000**	**19000**	**12500**	**7800**	**5000**	**3800**	**2900**	**2200**								
1	1	wet or damp	hand-feet	k	75								10	75-100	30	125-150	40	150-175	150	> 200
				Z_b	24000	14250	9375	5850	3750	2850	2175	1650								
				Z_c	1200															
				Z	25200	15450	10575	7050	4950	4050	3375	2850								
				I	**0.99**	**3.24**	**7.09**	**14.18**	**25.25**	**37.04**	**51.85**	**70.18**								
2			hands-feet	k	50									75		100-125		125-150		> 200
				Z_b	16000	9500	6250	3900	2500	1900	1450	1100								
				Z_c	1200															
				Z	17200	10700	7450	5100	3700	3100	2650	2300								
				I	**1.45**	**4.67**	**10.07**	**19.61**	**33.78**	**48.39**	**66.04**	**86.96**								
3			hand-foot	k	100									75-100		150		150-175		> 200
				Z_b	32000	19000	12500	7800	5000	3800	2900	2200								
				Z_c	1200															
				Z	33200	20200	13700	9000	6200	5000	4100	3400								
				I	**0.75**	**2.48**	**5.47**	**11.11**	**20.16**	**30.00**	**42.68**	**58.82**								
4	2		hand-hand	k	100								25	125-150	75	175-200	100	> 200	375	> 200
				Z_b	32000	19000	12500	7800	5000	3800	2900	2200								
				Z_c	200															
				Z	32200	19200	12700	8000	5200	4000	3100	2400								
				I	**0.78**	**2.60**	**5.91**	**12.50**	**24.04**	**37.50**	**56.45**	**83.33**								
5			hand-seat	k	50								14.29	75-100	42.86	100-125	57.14	125-150	214.29	> 200
				Z_b	16000	9500	6250	3900	2500	1900	1450	1100								
				Z_c	200															
				Z	16200	9700	6450	4100	2700	2100	1650	1300								
				I	**1.54**	**5.15**	**11.63**	**24.39**	**46.30**	**71.43**	**106.06**	**153.85**								
6			hands-seat	k	25									50-75		75-100		100-125		175-200
				Z_b	8000	4750	3125	1950	1250	950	725	550								
				Z_c	200															
				Z	8200	4950	3325	2150	1450	1150	925	750								
				I	**3.05**	**10.10**	**22.56**	**46.51**	**86.21**	**130.43**	**189.19**	**266.67**								

Table I.5/K.64 – Corresponding voltage limits for "b" and "c_1" curves

Case	Environ-ment type	Condition of shoes	Path contact	Voltage contact [Volt]	25	50	75	100	125	150	175	200	Limit current a.c. for 'b'curve [mA]	Voltage range corres-ponding to limit current a.c. [V]	Limit current d.c. for 'b' curve [mA]	Voltage range corres-ponding to limit current d.c. [V]	Limit current a.c. for 'c_1' curve [mA]	Voltage range corres-ponding to limit current a.c. [V]	Limit current d.c. for 'c_1' curve [mA]	Voltage range corres-ponding to limit current d.c. [V]
				Impedance of human body with respect to surface contact and voltage contact [ohm]	32000	19000	12500	7800	5000	3800	2900	2200								
7	3		hand-hand	k	100								25	125	75	175-200	100	> 200	375	> 200
				Z_b	32000	19000	12500	7800	5000	3800	2900	2200								
				Z_c	0															
				Z	32000	19000	12500	7800	5000	3800	2900	2200								
				I	**0.78**	**2.63**	**6.00**	**12.82**	**25.00**	**39.47**	**60.34**	**90.91**								
8			hand-seat	k	50								14.29	75-100	42.86	100-125	57.14	125-150	214.29	> 200
				Z_b	16000	9500	6250	3900	2500	1900	1450	1100								
				Z_c	0															
				Z	16000	9500	6250	3900	2500	1900	1450	1100								
				I	**1.56**	**5.26**	**12.00**	**25.64**	**50.00**	**78.95**	**120.69**	**181.82**								
9			hands-seat	k	25									50-75		75-100		100-125		150-175
				Z_b	8000	4750	3125	1950	1250	950	725	550								
				Z_c	0															
				Z	8000	4750	3125	1950	1250	950	725	550								
				I	**3.13**	**10.53**	**24.00**	**51.28**	**100.00**	**157.89**	**241.38**	**363.64**								

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Printed in Switzerland
Geneva, 2004