INTERNATIONAL TELECOMMUNICATION UNION

# ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

**K.33**
(10/96)

SERIES K: PROTECTION AGAINST INTERFERENCE

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# Limits for people safety related to coupling into telecommunications system from a.c. electric power and a.c. electrified railway installations in fault conditions

ITU-T Recommendation K.33

(Previously "CCITT Recommendation")

ITU-T K-SERIES RECOMMENDATIONS

**PROTECTION AGAINST INTERFERENCE**

*For further details, please refer to ITU-T List of Recommendations.*

# FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The 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 Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation K.33 was prepared by ITU-T Study Group 5 (1993-1996) and was approved by the WTSC (Geneva, October 9-18, 1996).

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NOTES

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

2. The status of annexes and appendices attached to the Series K Recommendations should be interpreted as follows:

– an *annexe* to a Recommendation forms an integral part of the Recommendation;

– an *appendice* to a Recommendation does not form part of the Recommendation and only provides some complementary explanation or information specific to that Recommendation.

# CONTENTS

## SUMMARY

This Recommendation gives limiting values of voltages on a telecommunications line caused by a fault occurring on a nearby a.c. electric power or a.c. electrified railway line, shows the way these values have been developed and provides guidance on how to calculate limiting values also in cases where the given values are not applicable.

## INTRODUCTION

This Recommendation is based on experience gained by telecommunications operators over some decades and takes into account the latest findings.

In determining a safe admissible voltage, a number of factors may be taken into account.

These factors include:

- biological data;
- the applicable current paths through the body;
- the impedances in the circuit;
- working practice in use.

# LIMITS FOR PEOPLE SAFETY RELATED TO COUPLING INTO TELECOMMUNICATIONS SYSTEM FROM A.C. ELECTRIC POWER AND A.C. ELECTRIFIED RAILWAY INSTALLATIONS IN FAULT CONDITIONS

*(Geneva, 1996)*

## 1 Scope

This Recommendation concerns safety problems for people coming in contact with telecommunications circuits exposed to the induction of a.c. electric power or a.c. electrified railway lines.

This Recommendation considers only short duration induction such as produced by faults on the inducing lines.

This Recommendation does not take into consideration:

– the steady state induced voltages;

– the admissible voltages for equipment and cables;

– the case of energization of the telecommunications line due to contact with an inducing line.

This Recommendation does not define safe working practices; however, consideration of working practices is an important part of the method used to define acceptable limiting values. The telecommunications operator has to coordinate the limit setting procedure with the use of appropriate working practices.

Guidance on working practices which can be applied is given in Volume VII of the Directives [1].

In the normal operation of telecommunications terminal equipment and where relevant Recommendations are applied, the general public are not expected to be exposed to danger from the common mode voltages and currents induced on the lines.

## 2 Establishing limits

For physiological reasons, limiting values to ensure safe working conditions are based on current data as specified in IEC Publication 479-1, *Effects of currents passing through the human body* [2]. However, for coupling processes as specified in the scope of this Recommendation, it is appropriate to establish limiting values in terms of voltages.

## 3 Admissible currents

### 3.1 Effects of alternating currents within the frequency range 15 to 150 Hz

The effects of alternating currents within the frequency range 15 Hz to 150 Hz on the human body are considered in IEC 479-1 [2]. The physiological effects of the current in the path left hand-to-feet are summarized in that Publication under the form of a diagram defining time/current zones of effects of a.c. currents on persons. The diagram is reproduced in Figure 1.

The zones in Figure 1 are defined as follows:

- Zone 1 – normally no perception;
- Zone 2 – normally no dangerous pathological effect;
- Zone 3 – normally no organic trouble;

- Zone 4 – fibrillation probability less than 5%;
- Zone 5 – fibrillation probability between 5% and 50%;
- Zone 6 – fibrillation probability higher than 50%.

In order to establish voltage limits, the appropriate time/current zones from those given above are to be selected taking into account the training of personnel, work instructions and practices, practical experience, and national regulations.

For the purpose of this Recommendation, the following time/current zones are considered appropriate:

– Zone 4 for a typical situation; or

– Zone 3 for a severe situation as specified under 6.3.

Zone 4 has been chosen for the typical case allowing for the facts that the limits given in IEC 479-1 are conservative estimates and the typical situation given here refers only to experienced and trained telecommunications personnel.

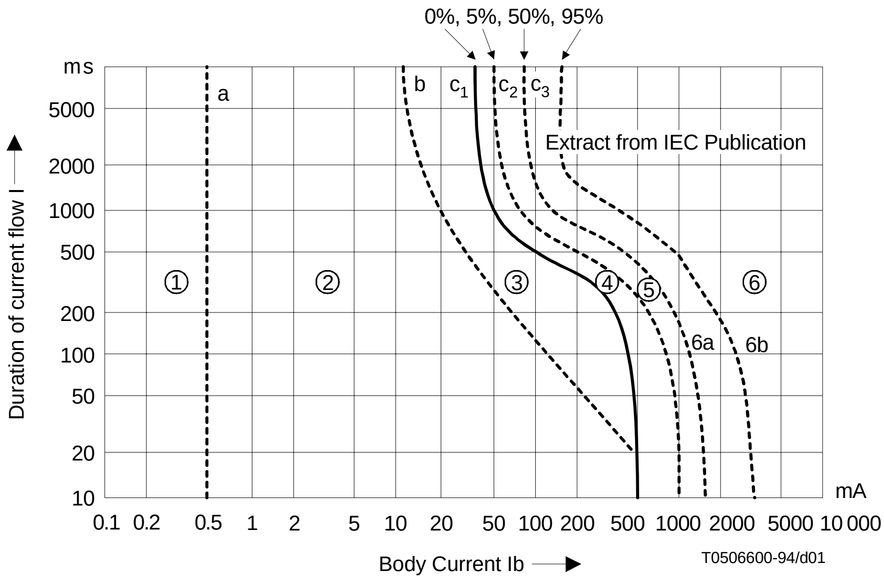



FIGURE 1/K.33

**Time/current zones of effects of a.c. current (15 to 150 Hz) on human beings**

## 3.2 Heart current factor

The curves in Figure 1 are also valid for other paths than the path left hand-to-feet but it is then necessary to introduce the heart current factor. This factor represents the ratio between the current densities in the heart for the considered path and the path left hand-to-feet when the current flowing in the two paths is of the same magnitude.

The current through paths other than left hand-to-feet that represent the same risk of ventricular fibrillation as that through the path left hand-to-feet as given in Figure 1 can be calculated using the following equation:

$$I_x = I_{ref}/F \quad (3\text{-}1)$$

with:

F the heart current factor;

$I_X$ the current for a given path;

$I_{ref}$ the reference current (for path left hand-to-feet).

The heart current factors as given in IEC 479-1 are reproduced in Table 1.

TABLE 1/K.33

**Heart current factor for various current paths**

| Current path | Heart current factor F |
|---|---|
| Left hand to left foot, right foot or feet | 1.0 |
| Both hands to feet | 1.0 |
| Left hand to right hand | 0.4 |
| Right hand to left foot, right foot or 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 |

For example, a current of 200 mA hand-to-hand has the same effect as a current of 80 mA in the reference path from left hand-to-feet.

# 4 Equivalent circuit for calculating the body current

## 4.1 General

Figure 2 gives the equivalent circuit for an induced element (i.e. conductor of a circuit, cable screen or cable sheath) of a telecommunication installation being touched.

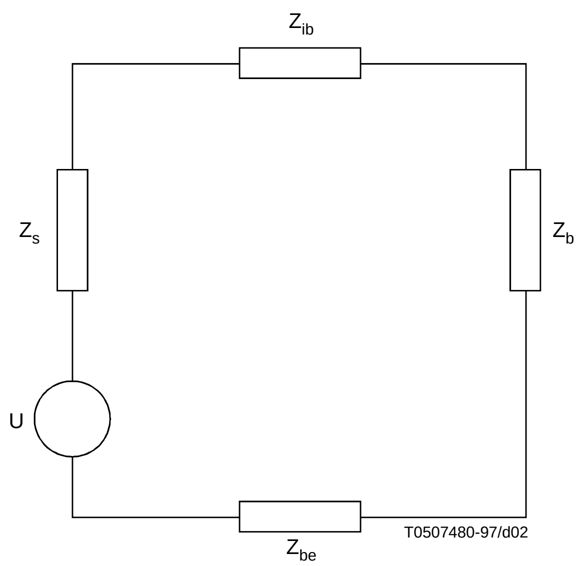



FIGURE 2/K.33

**Equivalent circuit for contact with an induced element**

The parameters appearing in Figure 2 are the following:

- U voltage between the induced element and the reference earth at the point where the contact happens, calculated according to Volumes II and III of the Directives [1];
- $Z_s$ source impedance;
- $Z_b$ total body impedance;
- $Z_{ib}$ impedance between the body and the induced element;
- $Z_{be}$ impedance between the body and earth.

## 4.2 Impedances in the equivalent circuit

### 4.2.1 Source impedance $Z_s$

The source impedance is the common mode impedance of the loop formed by the touched element (conductor, cable sheath or screen) with earth return.

The value of the source impedance can be calculated by the method presented in Volumes II and III of the Directives [1].

A conductor of a telecommunication circuit can be isolated from earth (e.g. coaxial tube) or permanently connected to earth through low impedances (e.g. subscriber lines at the exchange end). Earth connections may also appear during operation of gas discharge tubes installed at ends or at intermediate points of the line due to excessive voltage.

A metallic cable sheath is usually connected to earth through relatively low impedances either continuously along the line or at one or both ends and some intermediate points. In some cases, cable sheaths without earth connections are used.

In the absence of actual data or for general purposes, one of the following values might be chosen:

- $Z_s = 0\ \Omega$ for worst case consideration, e.g. short subscriber lines or bare wires;
- $Z_s = 180\ \Omega$ empirical value that is exceeded by 95% of induced circuits.

### 4.2.2 Total body impedance $Z_b$

The total body impedance is a function of touch voltage and varies from person-to-person. IEC 479-1 [2] gives, for different touch voltages and different paths, total body impedances which are not exceeded by more than 5%, 50% and 95% of the population.

The total body impedance is the sum of the internal body impedance and the skin impedance. Values of the total body impedance are given in Table 2 and Figure 3. They are valid for live human beings for the current paths of hand-to-hand or hand-to-foot for large contact areas (50 to 100 $cm^2$) and for touch voltages up to 5000 V.

The internal impedance of the body depends on the current path. Figure 4 shows the internal impedance of the human body for various current paths expressed as a percentage of that related to the path hand-to-hand.

The skin impedance depends on the skin status (people working with their hands usually have higher skin impedances than people working in the office), the contact pressure and the contact area (the lower the area the higher the impedance).

TABLE 2/K.33

**Total body impedances for various touch voltages**

| Touch voltage in V | Values for the total body impedance in Ω that are not exceeded for a percentage of the population of: | | |
|---|---|---|---|
| | 5% | 50% | 95% |
| 25 | 1750 | 3250 | 6100 |
| 50 | 1450 | 2625 | 4375 |
| 75 | 1250 | 2200 | 3500 |
| 100 | 1200 | 1875 | 3200 |
| 125 | 1125 | 1625 | 2875 |
| 220 | 1000 | 1350 | 2125 |
| 700 | 750 | 1100 | 1550 |
| 1000 | 750 | 1050 | 1500 |
| Asymptotic value | 650 | 750 | 850 |

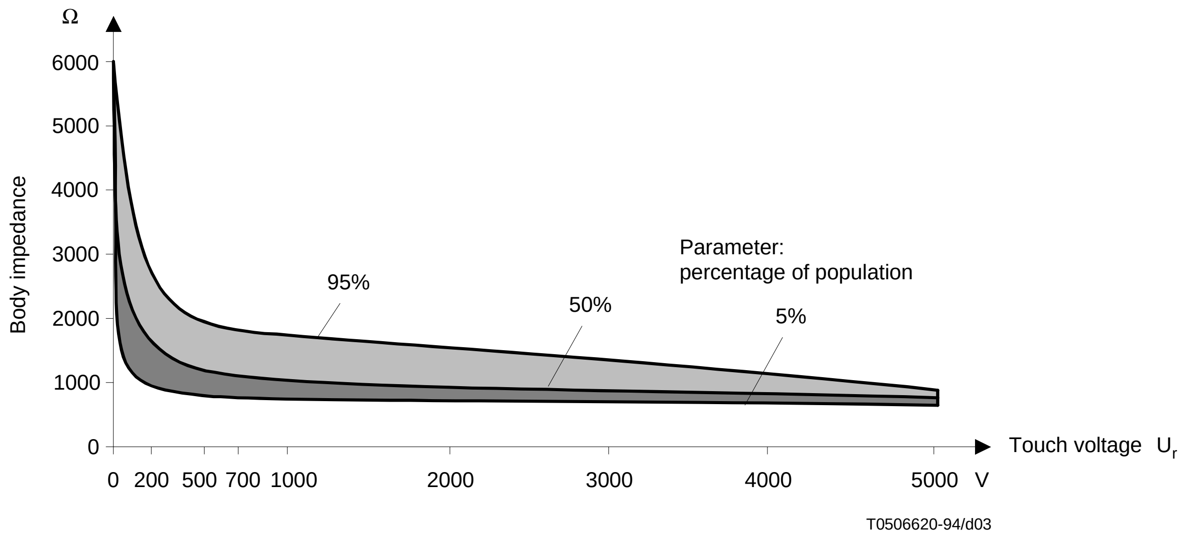



FIGURE 3/K.33

**Statistical values of total body impedances**

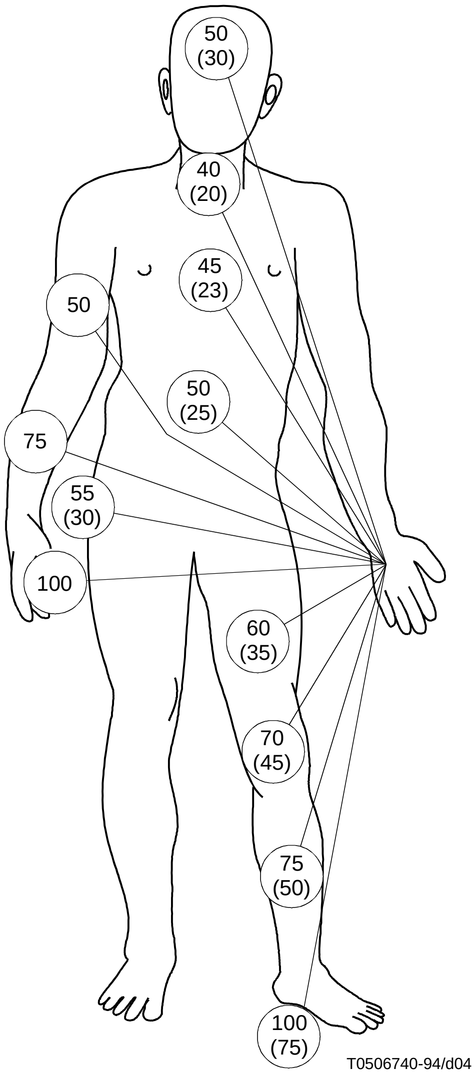
### 4.2.3 Impedance between the body and the induced element $Z_{ib}$

The impedance depends widely on work practices. If the working practice in use by the operator assures sufficient safety precautions that prevent harmful contacts, this impedance tends to infinity.

In the absence of such precautions or when actual data are not available:

$$Z_{ib} = 0\ \Omega$$

may be assumed as the extremely unfavourable case.




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

The numbers not in brackets refer to the current paths from one hand to the part of the body in question. The numbers in brackets refer to current paths between two hands and the corresponding part of the body.

NOTES

1 The impedance from one hand to both feet is 75% and the impedance from both hands to both feet is 50% of the impedance from hand-to-hand.

2 As a first approximation the percentages are also valid for the total body impedance.

FIGURE 4/K.33

**Internal impedance of the human body as a function of the current path**

### 4.2.4 Impedance between body and earth $Z_{be}$

The impedance depends widely on work practices. If the working practice in use by the operator assures isolation from earth this impedance tends to infinity.

The contact between the body and earth is usually made by feet when the operator stands on the earth. In this case the impedance is the sum of the shoe impedance $Z_{sh}$ and the earthing resistance $Z_{ss}$.

Table 3 gives some examples of values for the shoe impedance.

TABLE 3/K.33

**Values of shoe impedance $Z_{sh}$ in kΩ**

| Type and state of shoes | Leather sole | Elastomer sole |
|---|---|---|
| Dry shoes | 3000 | 2000 |
| Wet or damp shoes, hard soil | 5 | 30 |
| Wet or damp shoes, loose soil | 0.25 | 3 |

The earthing resistance $Z_{ss}$ can be calculated as follows:

$$Z_{ss} = 1.5\,\rho \qquad (4\text{-}1)$$

with:

ρ being the soil resistivity in Ω m; and

$Z_{ss}$ the earthing resistance in Ω.

When the operator works near an earthed conductor such as metal constructions, the possibility to touch these earthed conductors should be examined and the impedance between the body and the earth should be determined.

## 5 Determination of limits

For setting limits for the admissible voltage, the following steps should be taken:

- define the possible ways to contact the induced telecommunication line according to the work practices and the local conditions;
- select the possible current path through the body and determine the appropriate heart current factor (see 3.2);
- determine the appropriate total body impedance $Z_b$ relevant to the applied voltage and the selected current path through the body (see 4.2.2);
- determine the appropriate values of the other impedances involved in the equivalent circuit $Z_s$, $Z_{ib}$, $Z_{be}$ taking into account the dependence on applied voltages (striking of arresters, breakdown of insulation and the like) (see 4.2.1, 4.2.3, 4.2.4);
- define the fault duration (information from the operator of the inducing system);
- define the appropriate time/current zone (see 3.1);
- identify the admissible body current $I_{adm}$ according to the selected risk of fibrillation and the fault duration (see 3.1 and 3.2).

Using the results of the above-mentioned investigations, the admissible voltage can be derived from equation (5-1):

$$U_{adm} = I_{adm} * (Z_s + Z_b + Z_{ib} + Z_{be}) \qquad (5\text{-}1)$$

with:

- $U_{adm}$ the admissible limit for the voltage that occurs between the induced element and earth at the point where that element can be touched;
- $I_{adm}$ the admissible body current;
- $Z_b$ the total body impedance that is voltage dependent (see Figure 3);
- $Z_s$, $Z_{be}$, $Z_{ib}$ the impedances of the equivalent circuit (if one of those tends to infinity, e.g. because of working practices, limitation due to relevant breakdown voltages must be observed).

# 6 Admissible limits

## 6.1 General

In subclauses 6.2 and 6.3, admissible limits are listed for a typical situation and a severe situation. The ways in which these limits have been obtained are shown in Appendix I for a typical situation and in Appendix II for a severe situation.

In cases where the assumptions made (see Appendix I or Appendix II respectively) are not applicable, limiting values may be calculated according to clause 5.

## 6.2 Admissible limits for a typical situation

The normal situation is characterized by the following aspects:

– the work is carried out by trained and experienced personnel;

– only current paths hand-to-hand and hand-to-feet are to be considered;

– the admissible current is to be taken from Figure 1, curve $c_2$.

The limits given in Table 4 are recommended for typical situation:

TABLE 4/K.33

**Limiting values for a typical situation**

| Duration of faults t (s) | Admissible limit (V) |
|---|---|
| t ≤ 0.1 | 2000 |
| 0.1 < t ≤ 0.2 | 1500 |
| 0.2 < t ≤ 0.35 | 1000 |
| 0.35 < t ≤ 0.5 | 650 |
| 0.5 < t ≤ 1.0 | 430 |

A voltage caused by a fault, the duration of which exceeds 1 s, is considered a steady state voltage and is with this outside the scope of this Recommendation.

In the case that the induced line is a conductor in a cable with earthed metallic sheath or screen and that it is terminated in isolating transformers at both ends, the 60% of the d.c. test voltage or 85% of the a.c. test voltage of the cable and of the transformers may be accepted as admissible voltage if it exceeds values given in Table 4.

The same may be applied if all conductors are fitted with lightning protectors at both ends, provided special precautions are used to prevent an inadmissible current flow through the body.

### 6.3 Admissible limits for a severe situation

The case where the aspects characterizing the typical situation are not applicable is referred to as a severe situation. A severe situation discussed within the ITU may be characterized by the following aspects:

- the current paths hand-to-hand, hand-to-feet, hand-to-chest and/or hand-to-hip are examined;
- the voltage dependence of the body impedance be considered;
- the touching area dependence of the body impedance is considered;
- the source impedance is neglected;
- the admissible current is taken from Figure 1, curve $c_1$.

The limits given in Table 5 are recommended for a severe situation that is based on the assumptions given in Appendix II.

TABLE 5/K.33

**Limiting values for severe situation**

| Duration of faults t<br>(s) | Admissible limit<br>General<br>(V) | Admissible limit<br>when current paths through chest or hip need not be considered<br>(V) |
|---|---|---|
| t ≤ 0.06 | 430 | 650 |
| t ≤ 0.1 | 430 | 430 |
| 0.1 < t ≤ 1.0 | 300 | 300 |

If in another severe situation the aspects as mentioned above and/or the assumptions made in Appendix II are not applicable, the admissible voltage may be calculated according to clause 5.

### References

[1] CCITT: Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines, *ITU*, Geneva, 1990.

[2] IEC Publication 479-1:1984, *Effects of currents passing through the human body*.

## Appendix I

## Calculating limiting voltages in a typical situation

The following assumptions are made:

- current paths: hand-to-feet and hand-to-hand;
- total body impedance: $Z_b = 750\ \Omega$;
- source impedance: $Z_s = 180\ \Omega$;

– shoe impedance: $Z_{sh}$ = 3000 Ω;

– other impedances: $Z_{ib} = Z_{ss}$ = 0 Ω;

– fault duration: t = 0.1 s, 0.2 s, 0.35 s, 0.5 s;

– threshold current: according to Figure 1, curve $c_2$.

The results of the calculation using equation (5-1) are given in Table I.1.

TABLE I.1/K.33

| Fault duration in s | 0.1 | | 0.2 | | 0.35 | | 0.5 | |
|---|---|---|---|---|---|---|---|---|
| Threshold current in mA | 850 | | 600 | | 400 | | 200 | |
| Current path | Hand-to-hand | Hand-to-feet | Hand-to-hand | Hand-to-feet | Hand-to-hand | Hand-to-feet | Hand-to-hand | Hand-to-feet |
| Heart current factor | 0.4 | 1.0 | 0.4 | 1.0 | 0.4 | 1.0 | 0.4 | 1.0 |
| Admissible current in mA | 2125 | 850 | 1500 | 600 | 1000 | 400 | 500 | 200 |
| Shoes impedance in Ω | – | 3000 | – | 3000 | – | 3000 | – | 3000 |
| Calculated voltage limit in V | 2092 | 3340 | 1395 | 2358 | 930 | 1572 | 465 | 786 |

The conservative assumptions related to some impedances and the good experience gained worldwide by many telecommunications operators over some decades justifies the use of rounded values as given in Table 4.

# Appendix II

## Calculating limiting voltages in a severe situation

The following assumptions are made:

– current path: hand-to-feet, hand-to-hand, hand-to-chest and hand-to-hip;

– total body impedance: $Z_b$ = 562 Ω (hand-to-feet),

– $Z_b$ = 750 Ω (hand-to-hand),

as for hand-to-chest and hand-to-hip the voltage dependence according to Figure 3 is considered;

– shoe impedance: $Z_{sh}$ = 3000 Ω;

– other impedances: $Z_s$ = 0 Ω,

– $Z_{ib} + Z_{be}$ = 0 Ω;

– fault duration: t = 0.06 s;

– threshold current: according to Figure 1, curve $c_1$.

The results of the calculation using equation (5-1) are given in Table II.1.

Considering good experience gained in severe conditions over 40 years, 430 V with 0.1 s duration and 300 V for duration up to 1.0 s, these values are recommended for the severe situation.

TABLE II.1/K.33

| Fault duration in s | 0.06 | | | |
|---|---|---|---|---|
| Threshold current in mA | 440 | | | |
| Current path | Hand-to-hand | Hand-to-feet | Hand-to-hip | Hand-to-chest |
| Heart current factor | 0.4 | 1.0 | 1.0 | 1.5 |
| Admissible current in mA | 1100 | 440 | 440 | 293 |
| Shoes impedance in Ω | – | 3000 | – | – |
| Calculated voltage limit in V | 825 | 1567 | (165) (Note) | (99) (Note) |
| NOTE – This value is calculated using the body impedance for 700 V induced voltage. The higher voltage limit is appropriate considering the higher body impedance due to the lower induced voltage. | | | | |

Studies on the relation between fault current and fault duration have shown that the most unfavourable effects on the human body occur at the duration of 0.2 s. Therefore, that fault duration may be used, if the actual data is not specified. Using the parameters given above and considering the small touching area (less than 10 $cm^2$) and the voltage dependence according to Figure 3, it can be shown that the body current does not exceed the value relevant to curve $c_1$, Figure 1.

Recently, a fault duration equal to or less than 0.06 s is becoming more and more effective. Therefore, the calculation in Table II.1 is made with this assumption.

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