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Effects of current on human beings and livestock - Part 2: Special aspects

Effets du courant sur l'homme et les animaux domestiques - Partie 2: Aspects particuliers

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Effets du courant passant par le corps humain

Deuxième partie: Aspects particuliers
Chapitre 4: Effets du courant alternatif de fréquence supérieure à 100 Hz
Chapitre 5: Effets des courants de formes d'onde spéciales
Chapitre 6: Effets des courants d'impulsion unique de courte durée

Effects of current passing through the human body

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by the Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This report has been prepared by IEC Technical Committee No. 64: Electrical Installations of Buildings.

This second edition replaces the first edition of IEC Publication 479, published in 1974.

The text of this report is based on the following documents:

Six Months' Rule	Reports on Voting
64(CO)149 64(CO)150 64(CO)155	64(CO)157 64(CO)158 64(CO)163

Further information can be found in the relevant Reports on Voting indicated in the table above.

The new edition of Publication 479 is divided into two parts each containing three chapters:

Part 1: General aspects:

- Chapter 1: Electrical impedance of the human body.
- Chapter 2: Effects of alternating current in the range of 15 Hz to 100 Hz.
- Chapter 3: Effects of direct current.

Part 2: Special aspects:

- Chapter 4: Effects of alternating current with frequencies above 100 Hz.
- Chapter 5: Effects of special waveforms of current.
- Chapter 6: Effects of unidirectional single impulse currents of short duration.

The following IEC publications are quoted in this report:

Publications Nos. 50 (551) (1982): International Electrotechnical Vocabulary (IEV), Chapter 551: Power Electronics.

50 (801) (1984): Chapter 801: Acoustics and Electro-acoustics.

EFFECTS OF CURRENT PASSING THROUGH THE HUMAN BODY

Part 2: Special aspects

CHAPTER 4: EFFECTS OF ALTERNATING CURRENT WITH FREQUENCIES ABOVE 100 Hz

1. General

Electric energy in the form of alternating current of higher frequencies than 50/60 Hz is increasingly used in modern electrical equipment, for example aircraft (400 Hz), power tools and electric welding (mostly up to 450 Hz), electrotherapy (using mostly 4000 Hz to 5000 Hz), switching mode power supplies (20 kHz to 1 MHz).

Little experimental data is available for this chapter, so that the information given herein should be considered as provisional only but may be used for the evaluation of risks in the ranges of frequencies concerned (see bibliography, page 44). Attention is also drawn to the fact, that the impedance of human skin decreases approximately inversely proportional to the frequency for touch voltages in the order of some tens of volts, so that the skin impedance at 500 Hz is only about one tenth of the skin impedance at 50 Hz and may be neglected in many cases. This holds even more true for higher frequencies. The impedance of the human body at such frequencies is therefore reduced to its internal impedance Z_i (see Chapter 1).

2. Scope

This chapter describes the effects of sinusoidal alternating current within the frequency ranges:

- above 100 Hz up to and including 1000 Hz (see Clause 4);
- above 1000 Hz up to and including 10000 Hz (see Clause 5);
- above 10000 Hz (see Clause 6).

3. Definitions

In addition to the definitions given in Part 1, the following definition applies:

3.1 *Frequency factor F_f*

Ratio of the threshold current for the relevant physiological effects at the frequency f to the threshold current at 50/60 Hz.

Note. – The frequency factor differs for perception, let-go and ventricular fibrillation.

4. Effects of alternating current in the frequency range above 100 Hz up to and including 1000 Hz

4.1 *Threshold of perception*

For the threshold of perception the frequency factor is given in Figure 9, page 11.

4.2 *Threshold of let-go*

For the threshold of let-go the frequency factor is given in Figure 10, page 11.

4.3 *Threshold of ventricular fibrillation*

For shock-durations longer than the cardiac cycle, the frequency factor for the threshold of fibrillation for longitudinal current paths through the trunk of the body is given in Figure 11, page 13.

For shock-durations shorter than the cardiac cycle no experimental data is available.

5. Effects of alternating current in the frequency range above 1000 Hz up to and including 10000 Hz

5.1 *Threshold of perception*

For the threshold of perception the frequency factor is given in Figure 12, page 13.

5.2 *Threshold of let-go*

For the threshold of let-go the frequency factor is given in Figure 13, page 13.

5.3 *Threshold of ventricular fibrillation*

Under consideration.

6. Effects of alternating current in the frequency range above 10000 Hz

6.1 *Threshold of perception*

For frequencies between 10 kHz and 100 kHz the threshold rises approximately from 10 mA to 100 mA (r.m.s. values).

For frequencies above 100 kHz the tingling sensation characteristic for the perception at lower frequencies changes into a sensation of warmth for current intensities in the order of some hundred milliamperes.

6.2 *Threshold of let-go*

For frequencies above 100 kHz there is neither experimental data nor reported incidents concerning the threshold of let-go.

6.3 *Threshold of ventricular fibrillation*

For frequencies above 100 kHz there is neither experimental data nor reported incidents concerning the threshold of ventricular fibrillation.

6.4 *Other effects*

Burns may occur at frequencies above 100 kHz and current magnitudes in the order of amperes depending on the duration of the current flow.

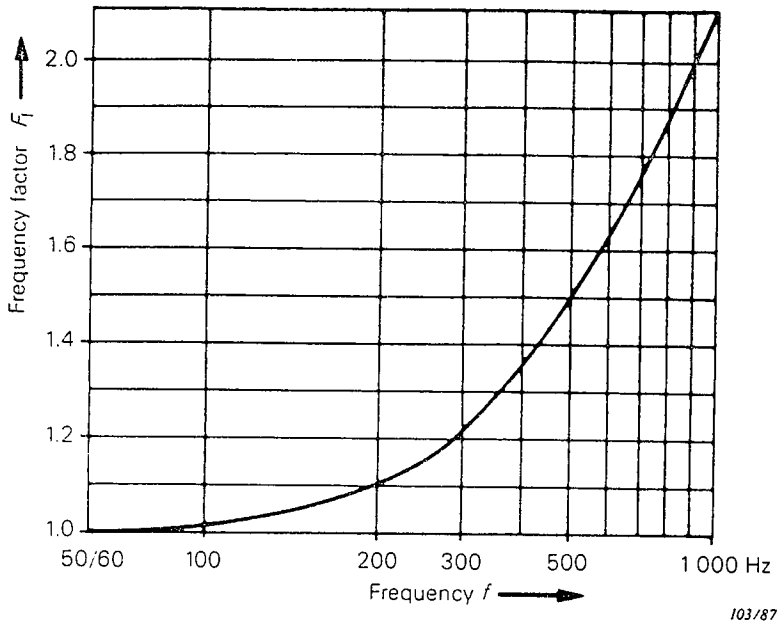

FIG. 9. – Variation of the threshold of perception within the frequency range 50/60 Hz to 1000 Hz.

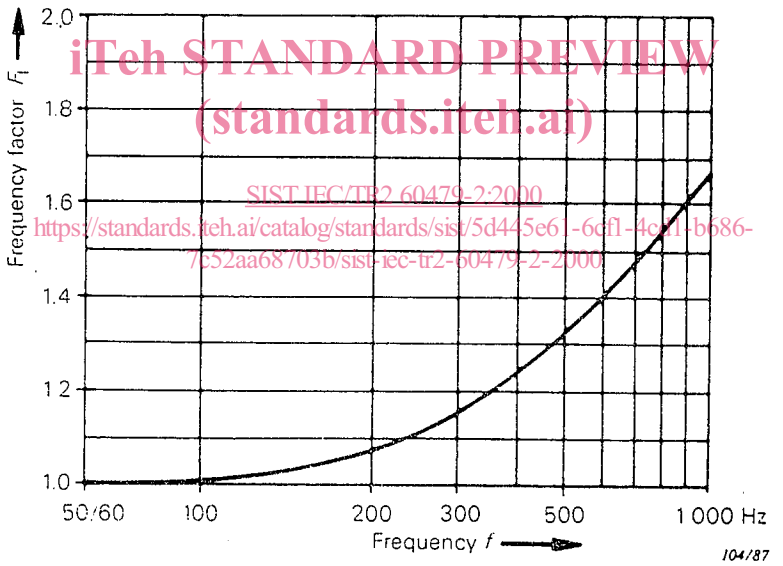

FIG. 10. – Variation of the threshold of let-go within the frequency range 50/60 Hz to 1000 Hz.

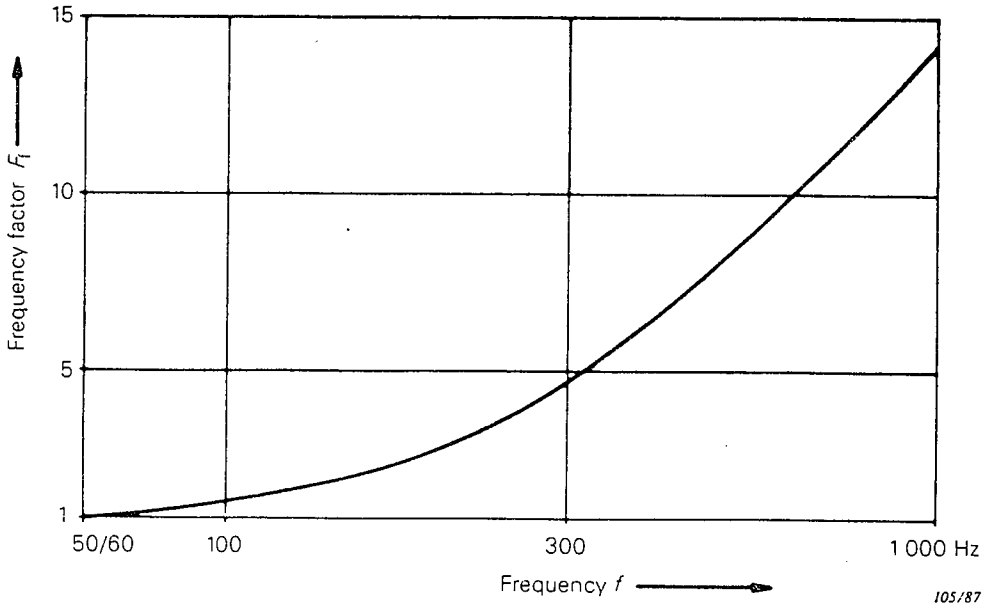

FIG. 11. – Variation of the threshold of ventricular fibrillation within the frequency range 50/60 Hz to 1000 Hz, shock-durations longer than one heart period and longitudinal current paths through the trunk of the body.

Note. – For shock-durations shorter than one heart period, other curves are under consideration.

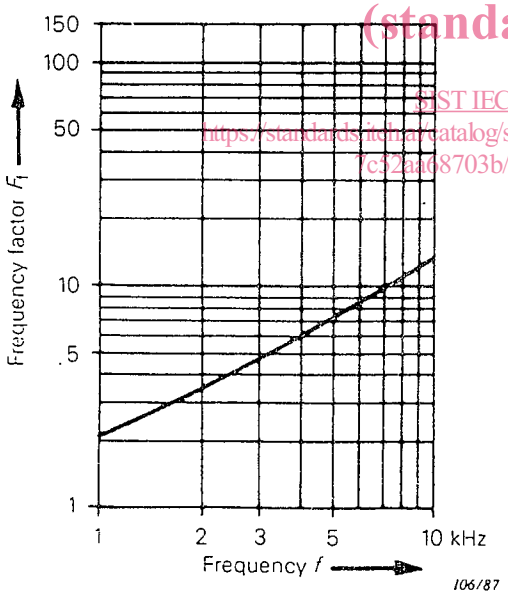

FIG. 12. – Variation of the threshold of perception within the frequency range 1000 Hz to 10000 Hz.

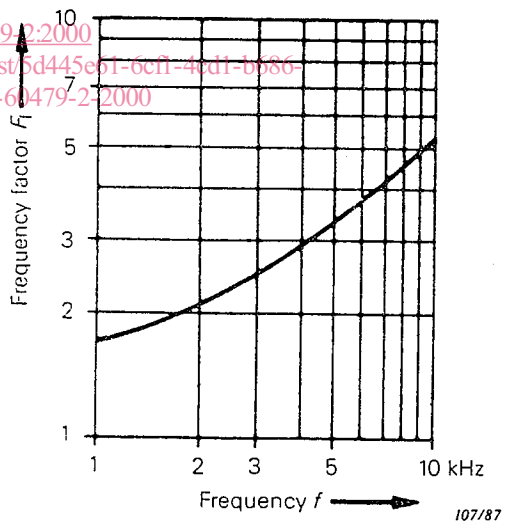

FIG. 13. – Variation of the threshold of let-go within the frequency range 1000 Hz to 10000 Hz.

CHAPTER 5: EFFECTS OF SPECIAL WAVEFORMS OF CURRENT

1. General

The increasing interest in special waveforms of current derived from alternating current and direct current is evidenced by the rising number of applications of electronic controls causing such types of current particularly in the case of an insulation fault. This holds true also for equipment using alternating currents with phase control and multicycle control.

As is to be expected the effects of such currents on the human body are between those caused by direct and by alternating current; therefore equivalent current magnitudes with regard to ventricular fibrillation can be established.

2. Scope

This chapter describes the effects of current passing through the human body for:

- alternating sinusoidal current with d. c. components.
- alternating sinusoidal current with phase control,
- alternating sinusoidal current with multicycle control.

Note. – Other waveforms are under consideration.

The information given is deemed applicable for alternating current frequencies from 15 Hz up to 100 Hz.

3. Definitions

In addition to the definitions given in Part 1, the following ones apply for the purpose of this chapter:

3.1 *Phase control*

The process of varying the instant within the cycle at which current conduction begins.

3.2 *Phase control angle* (current delay angle)

The time expressed in angular measure by which the starting instant of current conduction is delayed by phase control.

3.3 *Multicycle control*

The process of varying the ratio of the number of cycles which include current conduction to the number of cycles in which no current conduction occurs.

3.4 *Multicycle control factor p*

The ratio between the number of conducting cycles and the sum of conducting and non-conducting cycles in the case of multicycle control (see Figure 17, page 25).

4. Effects of alternating current with d. c. components

4.1 *Waveforms and frequencies*

Figure 14, page 23, shows typical waveforms which are dealt with in this clause. Pure d. c. and pure a. c. are represented as well as combined waveforms of various ratios a. c. to d. c. The following current magnitudes have to be distinguished:

I_{rms} = r. m. s. value of the current of the resultant waveform,

I_p = peak value of the current of the resultant waveform,

I_{pp} = peak-to-peak value of the current of the resultant waveform,

I_{ev} = r. m. s. value of a sinusoidal current presenting the same risk as regards ventricular fibrillation as the waveform concerned.

Note. – The current I_{ev} is used instead of the current I_B in Figure 5 of Chapter 2 to estimate the risk of ventricular fibrillation.

4.2 *Threshold of perception*

The threshold of perception depends on several parameters such as the area of the body in contact with an electrode (contact area), the conditions of contact (dry, wet, pressure, temperature) and also on physiological characteristics of the individual.

Values for the threshold of perception are under consideration.

4.3 *Threshold of let-go*

The threshold of let-go depends on several parameters, such as the contact area, the shape and size of the electrodes and also on the physiological characteristics of the individual.

Values for the threshold of let-go are under consideration.

4.4 *Threshold of ventricular fibrillation*

4.4.1 *Waveforms consisting of specific ratios of alternating to direct current*

The fibrillation hazard may be taken as being approximately the same as with an equivalent alternating current I_{ev} having the following characteristics:

a) For shock durations longer than approximately 1.5 times the period of the cardiac cycle, I_{ev} is the r. m. s. value of a current having the same peak-to-peak value I_{pp} as the current of the waveform concerned:

$$I_{ev} = \frac{I_{pp}}{2\sqrt{2}}$$

b) For shock durations shorter than approximately 0.75 times the period of the cardiac cycle, I_{ev} is the r. m. s. value of a current having the same peak value I_p as the current of the waveform concerned:

$$I_{ev} = \frac{I_p}{\sqrt{2}}$$

Note. – This correlation is the less applicable the smaller the ratio a. c. to d. c. becomes. For pure d. c. shocks of a duration less than 0.1 s the threshold is equal to the corresponding r. m. s. value of the alternating current (see Figure 5 and Figure 8 in Chapter 2 and Chapter 3 respectively).

c) In the duration range from 0.75 to 1.5 times the period of the cardiac cycle the amplitude parameter changes from peak value to peak-to-peak value.

Note. – The details of the nature of the transition that takes place are subject to further studies.

4.4.2 *Examples of rectified alternating current*

Figure 15, page 23, shows the waveforms for half wave and full wave rectification. For these waveforms the peak value of the current is identical with its peak-to-peak value.