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Partie 4:
Protection pour assurer la sécurité
Chapitre 44: Protection contre les surtensions
Section 442 – Protection des installations à basse tension contre les défauts à la terre dans les installations à haute tension

Electrical installations of buildings

Part 4:
Protection for safety
Chapter 44: Protection against overvoltages
Section 442 – Protection of low-voltage installations against faults between high-voltage systems and earth

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Commission Electrotechnique Internationale
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Международная Электротехническая Комиссия

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL INSTALLATIONS OF BUILDINGS

Part 4: Protection for safety
Chapter 44: Protection against overvoltages
Section 442 – Protection of low-voltage installations against faults between high-voltage systems and earth

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by 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.

This International Standard has been prepared by Technical Committee No. 64: Electrical installations of buildings.

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

Six Months' Rule	Report on Voting
64(CO)175	64(CO)213

Full information on the voting for the approval of this standard can be found in the Voting Report indicated in the above table.

Annex A is for information only.

INTRODUCTION

The rules of this section do not apply to systems which are wholly or partly under control of public power supply companies (see scope of IEC 364-1).

The fault-current flowing in the earth electrode of the exposed-conductive-parts of the sub-station causes a significant rise of the potential of the exposed-conductive-parts of the sub-station to the general mass of the earth, i.e. a fault-voltage, whose magnitude is governed by:

- the fault-current magnitude, and
- the resistance of the earth electrode of the exposed-conductive-parts of the sub-station.

The fault-current may cause:

- a general rise of the potential of the low-voltage system with respect to earth, i.e. stress-voltages which may cause a breakdown of the insulation in low-voltage equipment,
- a general rise of the potential of the exposed-conductive-parts of the low-voltage system with respect to earth, which may give rise to fault-voltage and touch voltages.

NOTE - In this section, the expression "high-voltage" (HV) refers to voltages exceeding the upper limit of voltage band II. The expression "low-voltage" (LV) refers to voltages not exceeding the upper limit of voltage band II.

ELECTRICAL INSTALLATIONS OF BUILDINGS

Part 4: Protection for safety
Chapter 44: Protection against overvoltages
Section 442 – Protection of low-voltage installations against faults between high-voltage systems and earth

442.1 General

442.1.1 *Scope and object*

The rules of this section are intended to provide for the safety of persons and equipment in a LV system in the event of a fault between the HV system and earth in the HV part of transformer stations which supply low-voltage systems.

442.1.2 *Fault-voltage*

The magnitude and the duration of the fault-voltage or the touch voltage due to an earth-fault in the high-voltage system shall not exceed the values given by curve F and T respectively of figure 44 A.

442.1.3 *Stress-voltage*

The magnitude and the duration of the power frequency stress-voltage of the LV equipment in the consumer's installation due to an earth fault in the high voltage system shall not exceed the values of table 44 A.

NOTES

1 The power-frequency stress-voltage is the voltage which appears across the insulation.

2 A higher stress-voltage is permitted for the low-voltage equipment of the sub-station if the insulation level of the equipment is compatible and under the conditions of clause 442.3.

Table 44 A

Permissible stress-voltages in LV installations V	Time s
1,5 U_n	> 5
1,5 U_n + 750	≤ 5

U_n nominal voltage line-to-earth of the low-voltage system.

442.1.4 *Normative references*

The following normative documents contain provisions which, through reference in this text, constitute provisions of this section. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this section are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid international standards.

IEC 364-1: 1992, *Electrical installations of buildings – Part 1: Scope, object and fundamental principles*

IEC 364-4-41: 1992, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 41: Protection against electric shock.*

IEC 479-1: 1984, *Effects of current passing through the human body – 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.*

442.2 Earthing systems in transformer sub-stations

At the transformer sub-station, there shall be one earthing system to which shall be connected:

- earth electrodes;
- the transformer tank;
- metallic coverings of high-voltage cables;
- metallic coverings of low-voltages cables except where the neutral conductor is earthed via a separate earth electrode;
- earth wires of high-voltage systems;
- the exposed-conductive-parts of high-voltage and low-voltage equipment;
- extraneous-conductive-parts.

442.3 Earthing arrangements in transformer sub-stations

The conditions enumerated under subclause 442.4 and 442.5 are deemed to be complied with if one or both of the conditions stated in subclause 442.3.1 or the condition in subclause 442.3.2 are met. Where none of the conditions of subclauses 442.3.1 or 442.3.2 is met the requirements of subclauses 442.4 and 442.5 shall be applied.

442.3.1 The transformer sub-stations are connected to:

- high-voltage cables with suitable earthed metallic coverings or
- low-voltage cables with suitable earthed metallic coverings or
- a combination of both high- and low-voltage cables with suitable earthed metallic coverings

and in all cases:

- the length of these cables exceeds 1 km.

442.3.2 The earthing resistance of the exposed-conductive-parts of the transformer sub-station does not exceed 1 Ω.

442.4 Earthing arrangements with regard to type of earthing systems in LV installations

442.4.1 *Symbols*

In the following subclauses, the symbols are:

I_m that part of the earth fault current in the high-voltage system that flows through the earth electrode of the exposed-conductive-parts of the transformer sub-station.

R is the resistance of the earth electrode of the exposed-conductive-parts of the transformer sub-station.

U_o is the line-to-neutral voltage of the low-voltage system.

U is the line-to-line voltage of the low-voltage system.

U_f is the fault-voltage in the LV system between exposed-conductive-parts and earth.

U_1 is the stress-voltage in the LV equipment of the transformer sub-station.

U_2 is the stress-voltage in the LV equipment of the consumer's system.

442.4.2 *TN-systems*

a) When the fault-voltage $R \times I_m$ is disconnected within a time given in figure 44 A, the neutral conductor of the LV system may be connected to the earthing electrode of the exposed-conductive-parts of the transformer sub-station (see TN-a in figure 44 B).

NOTE - If the exposed-conductive-part of the low voltage equipment of the consumer system is within the zone of influence of the main equipotential bonding, the touch voltage is zero (see section 413 of IEC 364-4-41).

b) If the condition under a) is not fulfilled, the neutral conductor of the LV system shall be earthed via an electrically independent earth electrode (see TN-b in figure 44 B). In this case, the conditions of 442.5.1 apply.

442.4.3 *TT-systems*

a) When the relation between the stress-voltage ($R \times I_m + U_o$) and the disconnecting time given in table 44 A is complied with for the LV equipment of the consumer's installation, the neutral conductor of the LV system may be connected to the earthing electrode of the exposed-conductive-parts of the transformer sub-station (see TT-a in figure 44 C).

b) If the condition under a) is not fulfilled, the neutral conductor of the LV system shall be earthed via an electrically independent earth electrode (see TT-b in figure 44 C). In this case, the conditions of 442.5.1 apply.

If the exposed-conductive-parts of the low-voltage equipment of the consumer system are within the zone of influence of the main equipment bonding the touch voltage is zero.

442.4.4 *IT-systems*

a) When the fault-voltage $R \times I_m$ is disconnected within a time given in figure 44 A, the exposed-conductive-parts of the LV equipment of the consumer's installation may be connected to the earthing electrode of the exposed-conductive-parts of the sub-station (see figures 44 D, 44 J and 44 K).

If this condition is not fulfilled, the exposed-conductive-parts of the LV equipment of the LV installation shall be connected to an earthing system electrically independent from the earthing electrode of the exposed-conductive-parts of the sub-station (see figures 44 E to 44 H).

b) When the exposed-conductive-parts of the LV equipment in the consumer's installation are earthed via an earth electrode electrically independent of the earth electrode of the transformer sub-station, and when the relation between the stress-voltage ($R \times I_m + U$) and the disconnecting time given in table 44 A is complied with for the LV equipment of the consumer's installation, the neutral impedance of the LV system, if any, may be connected to the earth electrode of the exposed-conductive-parts of the transformer sub-station (see figure 44 E).

If this condition is not fulfilled, the neutral impedance shall be earthed via an electrically independent earth electrode (see figures 44 F and 44 H). In this case, the conditions of 442.5.2 apply.

442.5 Limitation of stress-voltage in LV equipment of transformer sub-stations

442.5.1 *TN- and TT-systems*

When in TN- and TT-systems the neutral conductor is earthed via an earth electrode electrically independent of the earth electrode of the exposed-conductive-parts of the transformer sub-station (see figures TN – b in figure 44 B and TT – b in figure 44 C), the stress-voltage ($R \times I_m + U_o$) shall be disconnected in time compatible with the insulation level of the LV equipment of the transformer sub-station.

NOTE - The insulation level of the LV equipment of the transformer sub-station may be higher than the value given in table 44 A.

442.5.2 *IT-systems*

When in IT-systems both the exposed-conductive-parts of the consumer's installation and the neutral impedance, if any, are earthed via earth electrodes electrically independent of the earth electrode of the transformer sub-station (see figures 44 F, 44 G and 44 H), the stress-voltage ($R \times I_m + U$) shall be disconnected in a time compatible with the insulation level of the LV equipment of the transformer sub-station.

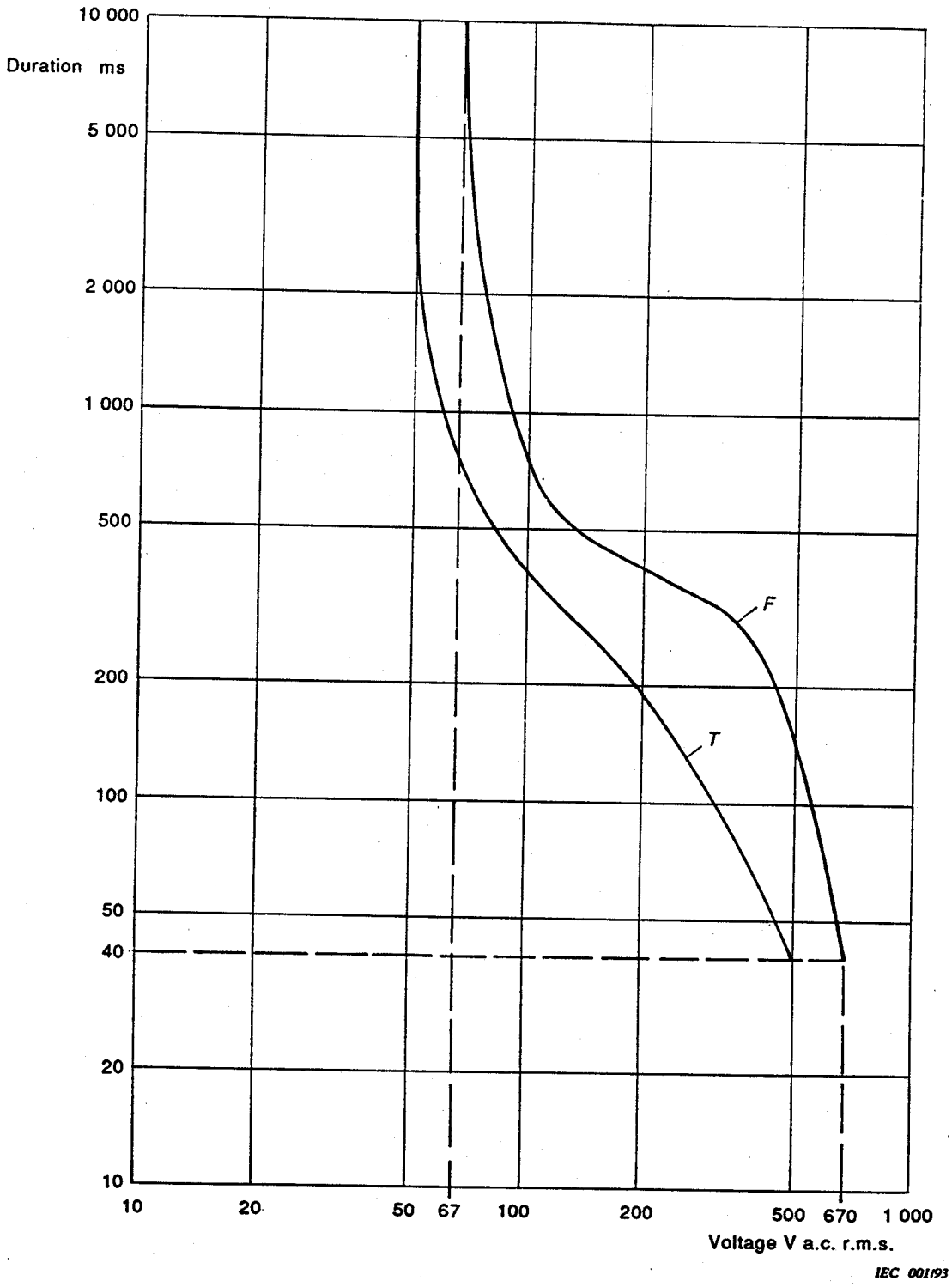
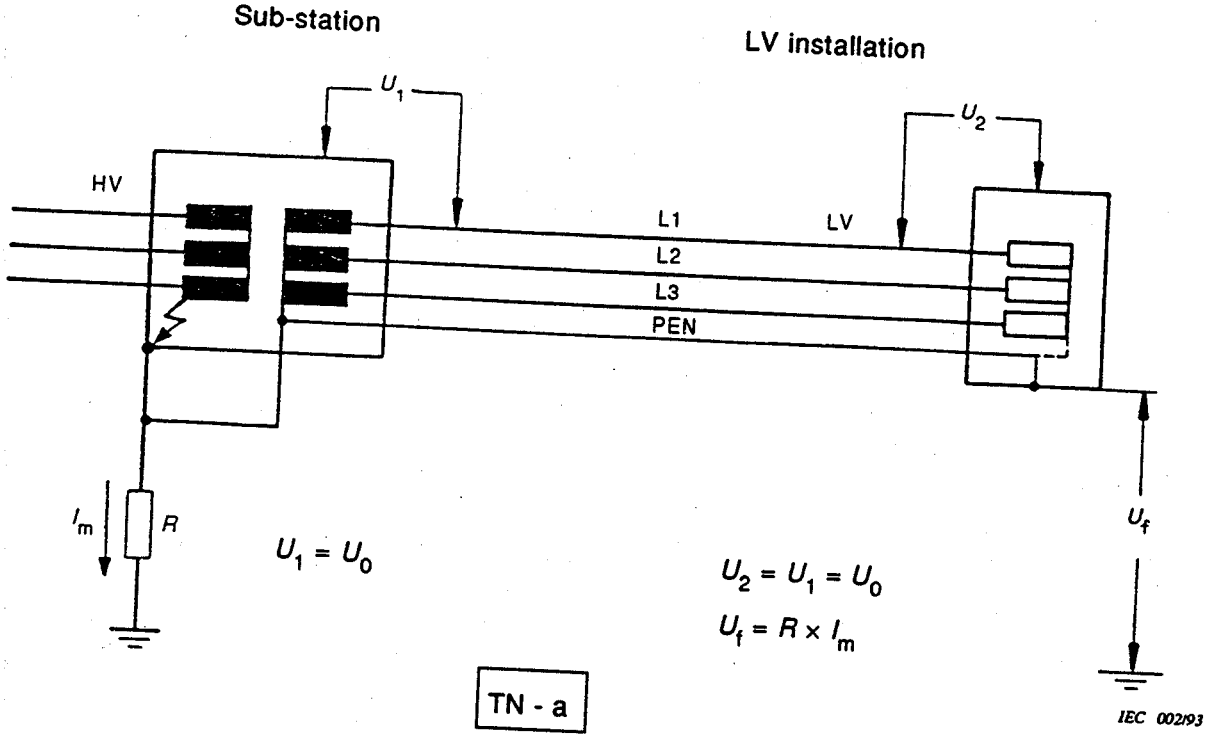
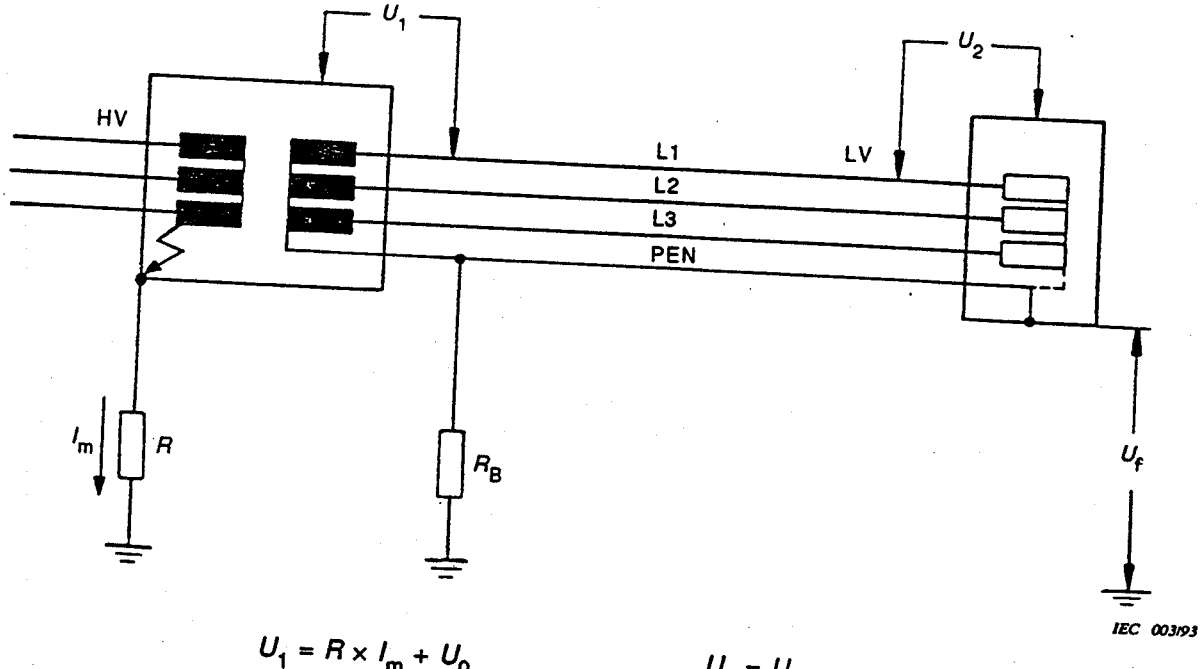


Figure 44 A – Maximum duration of fault-voltage *F* and touch voltage *T* due to an earth-fault in the HV system





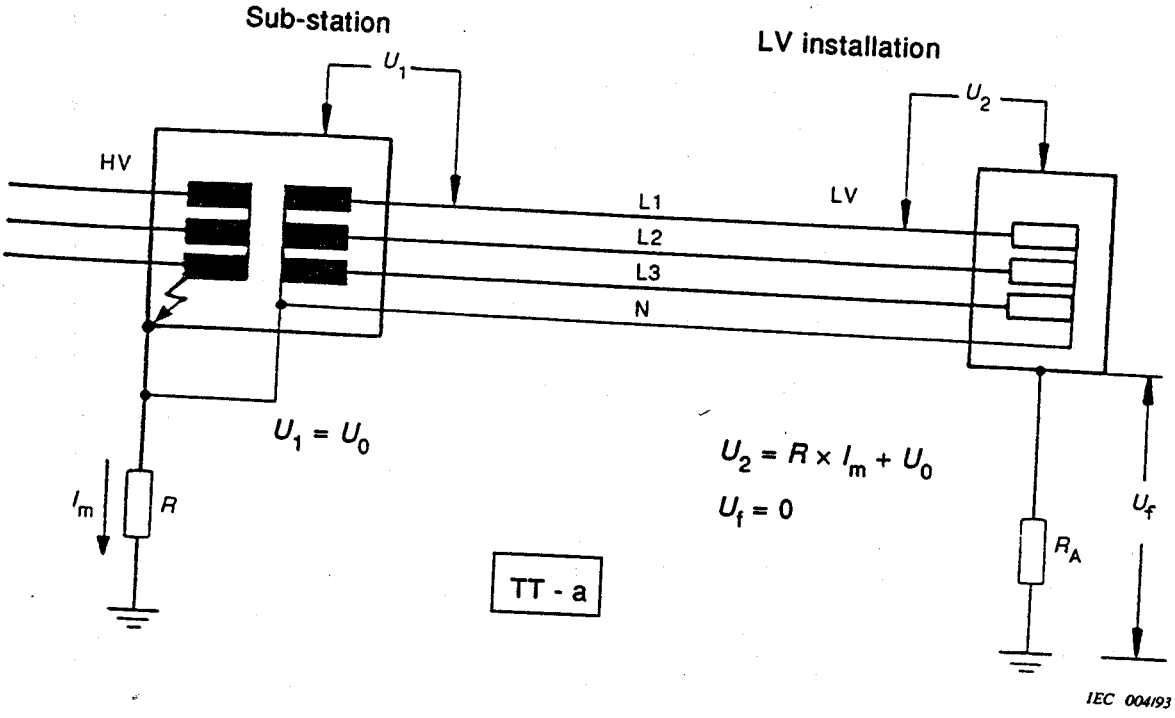
$U_1 = R \times I_m + U_0$

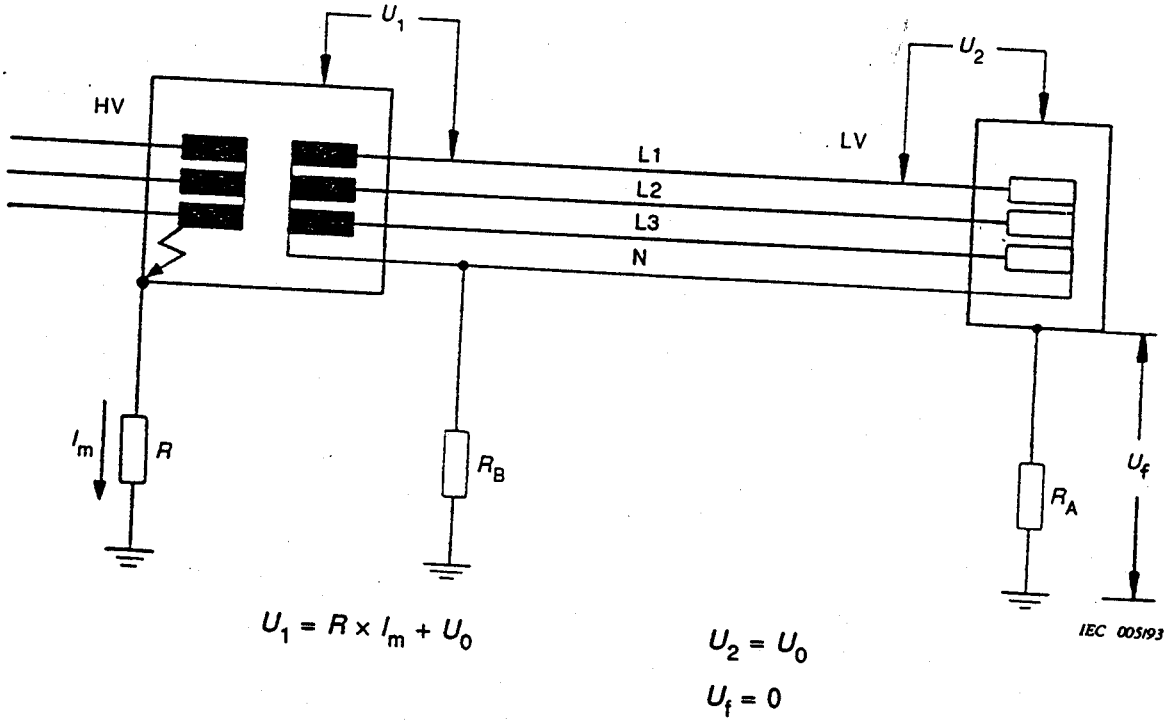
$U_2 = U_o$

$U_f = 0$

TN - b

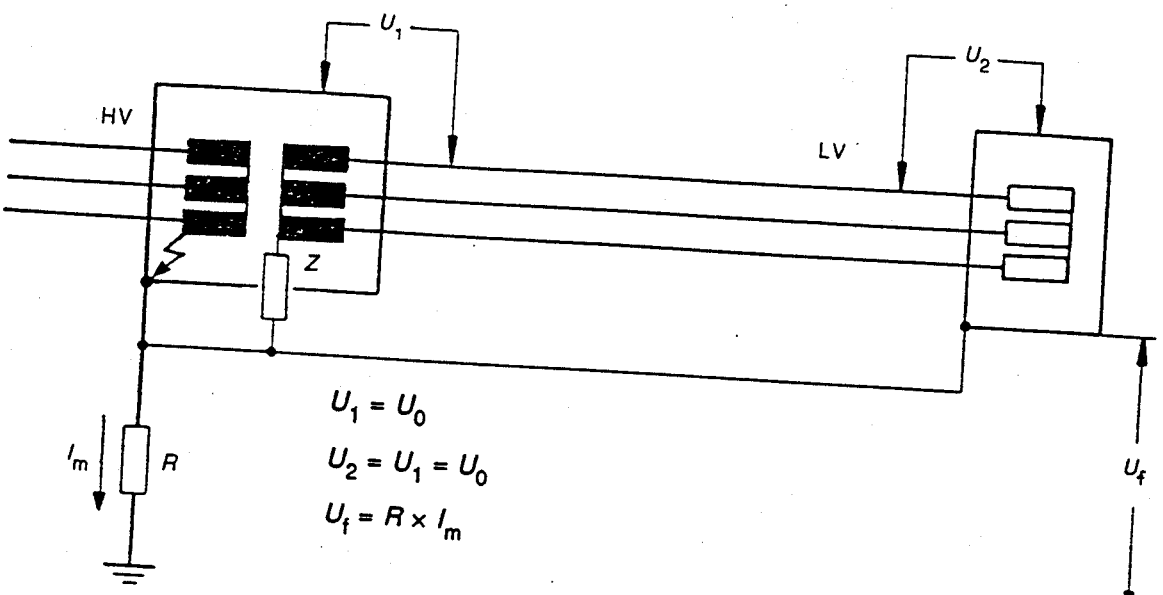
Figure 44 B – TN-systems



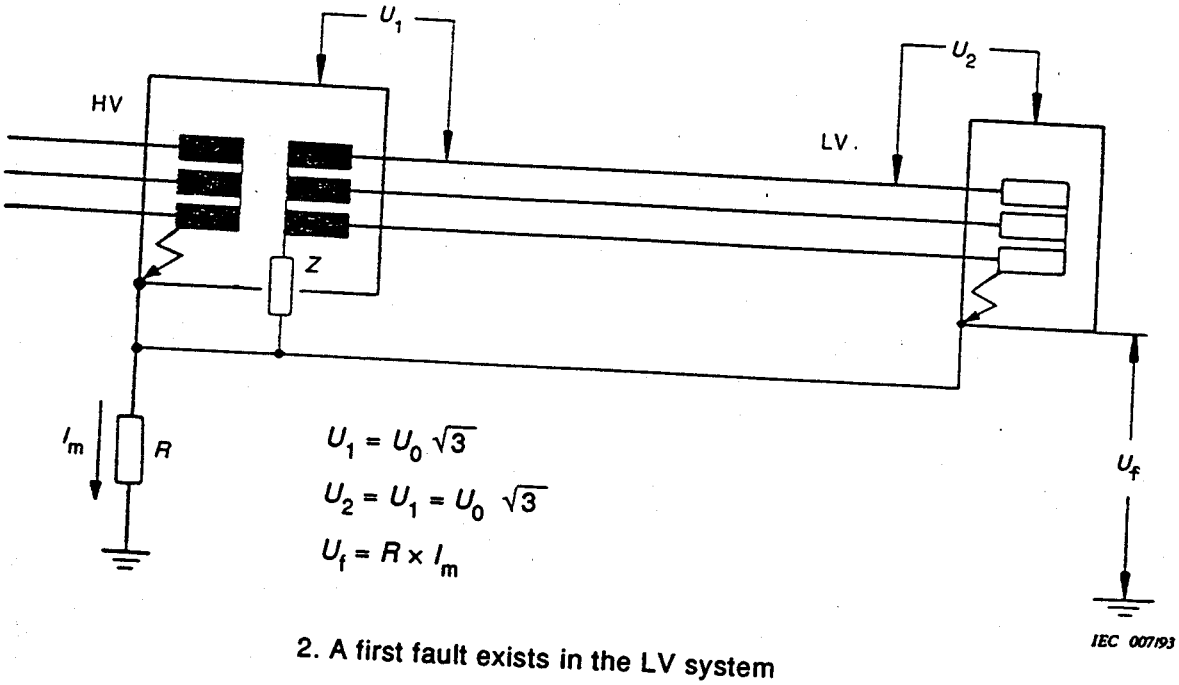


TT - b

Figure 44 C – TT –systems

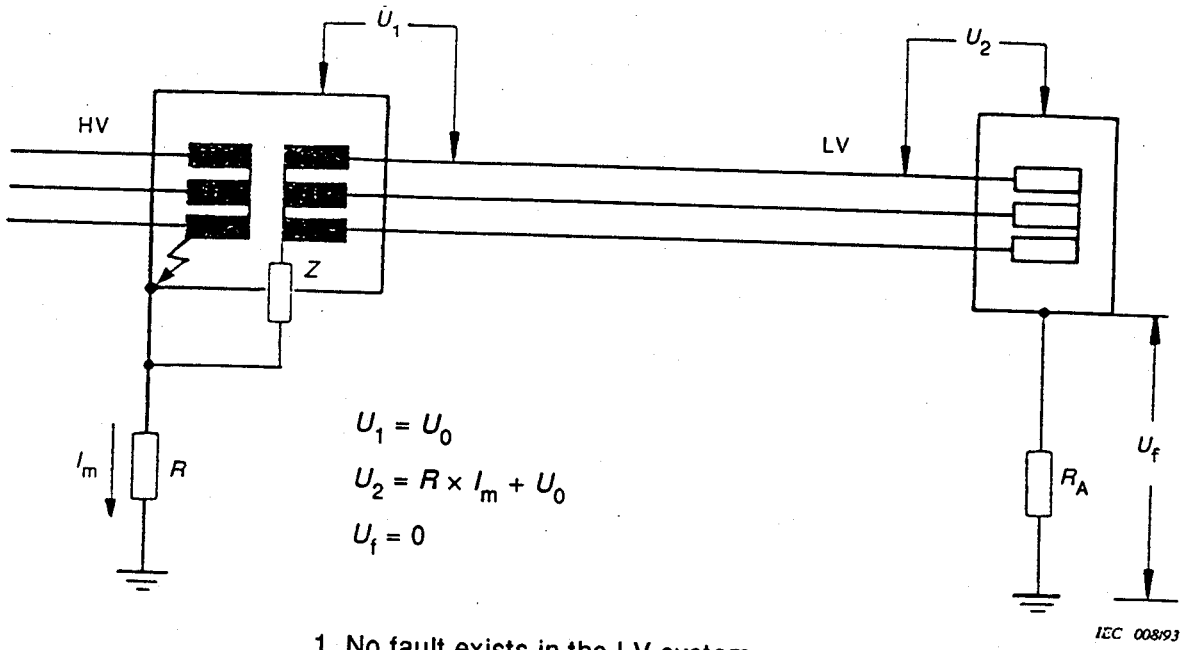


1. No fault exists in the LV system



2. A first fault exists in the LV system

Figure 44 D – IT-system, example a



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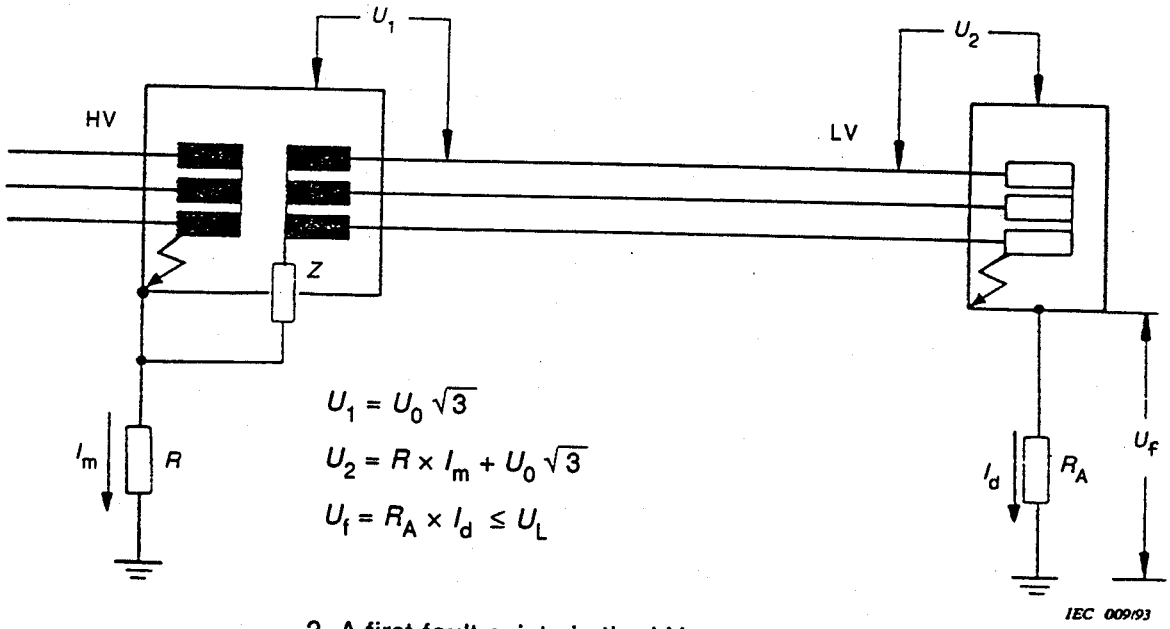
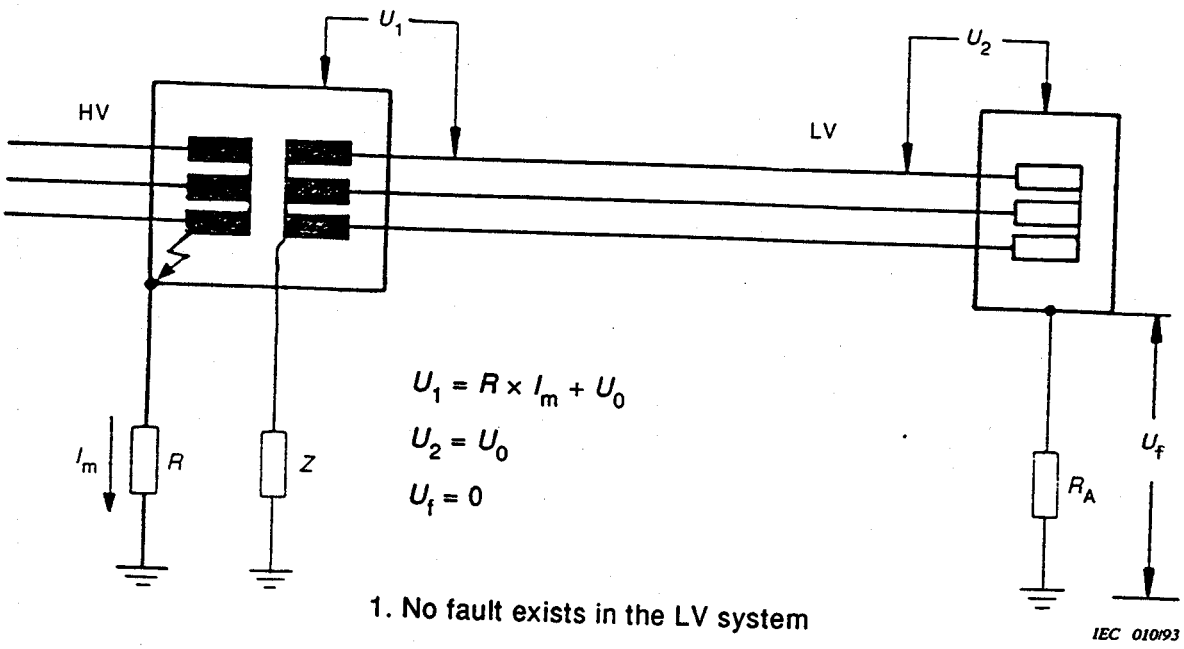
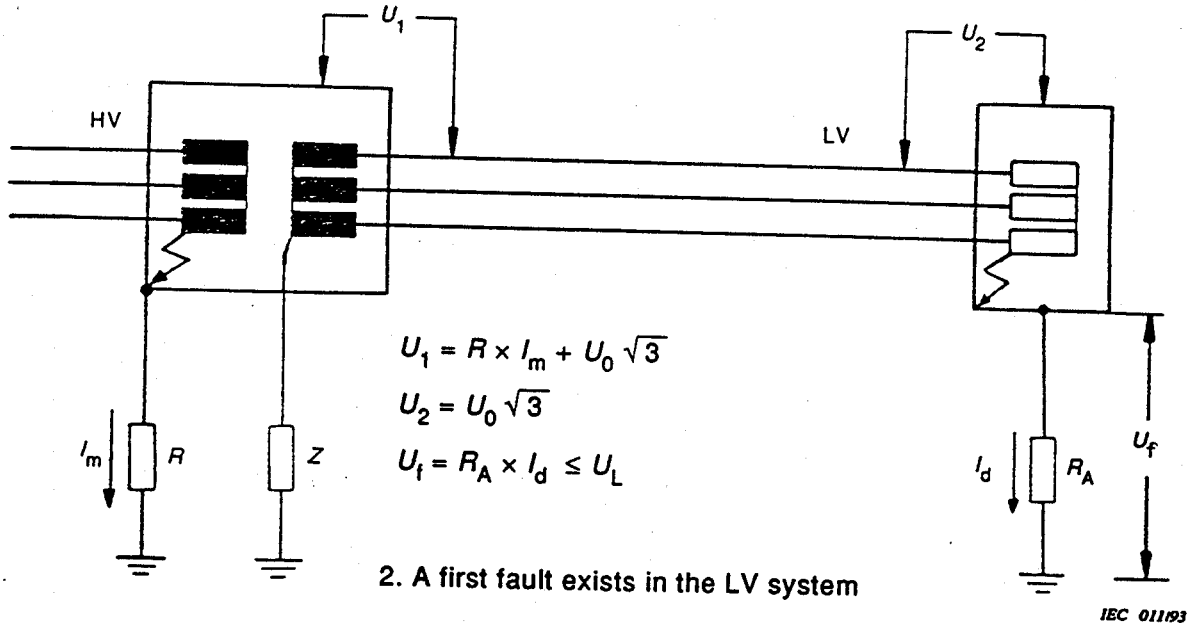


2. A first fault exists in the LV system

Figure 44 E – IT-system, example b

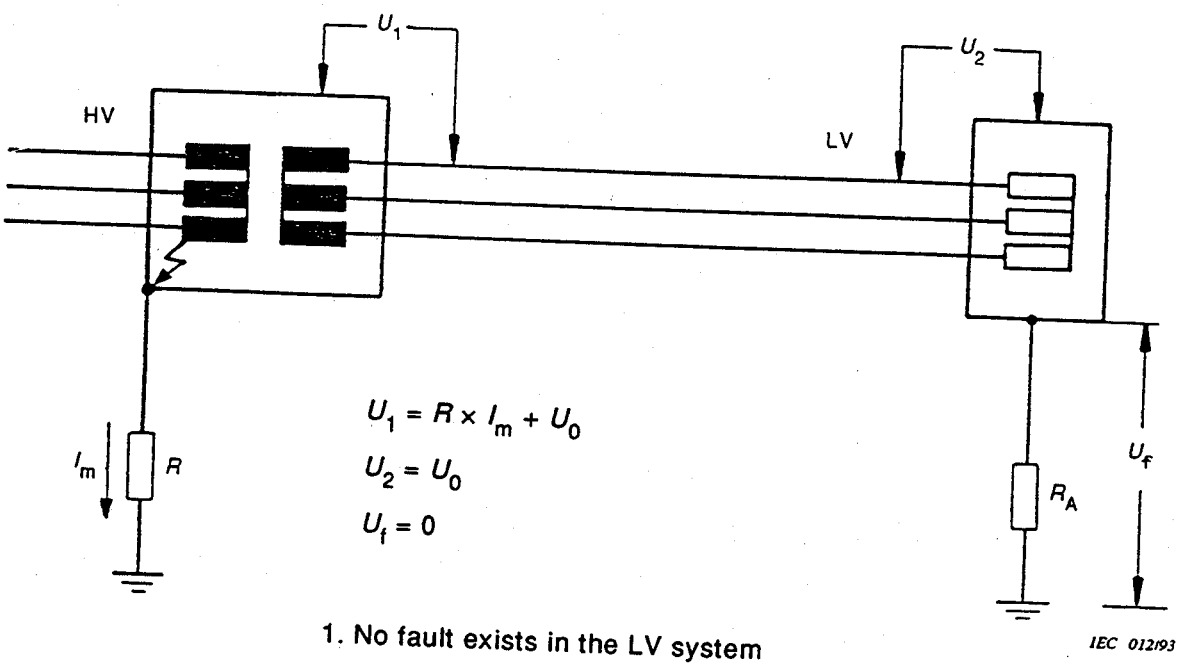


1. No fault exists in the LV system

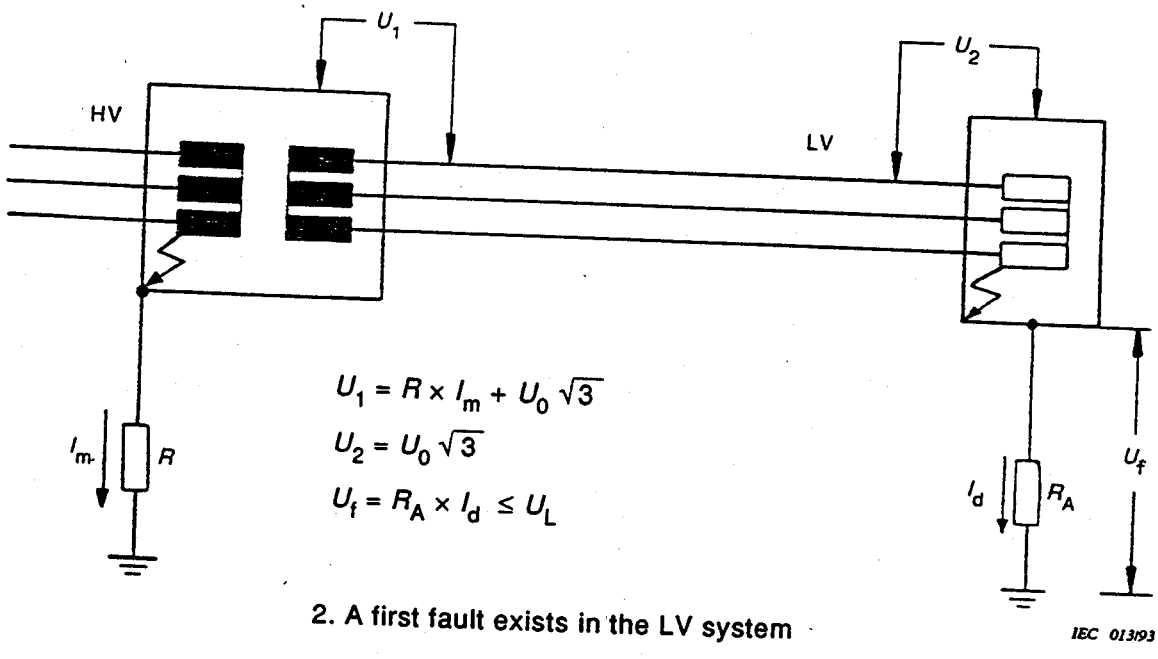


2. A first fault exists in the LV system

Figure 44 F – IT-system, example c1

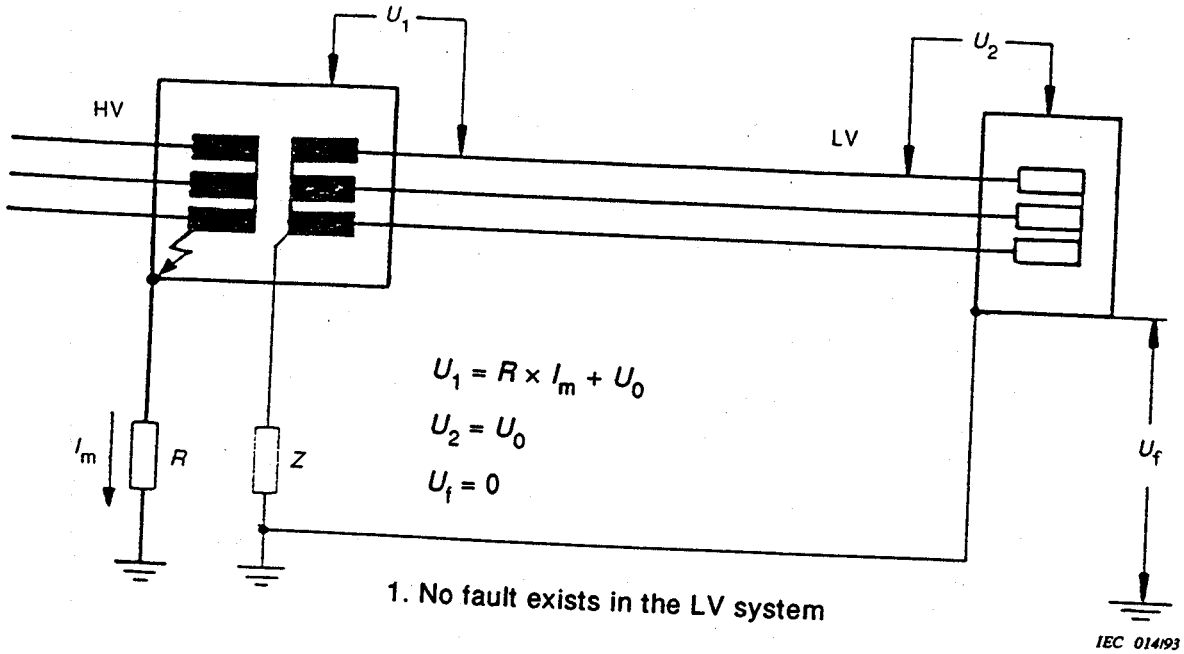


1. No fault exists in the LV system

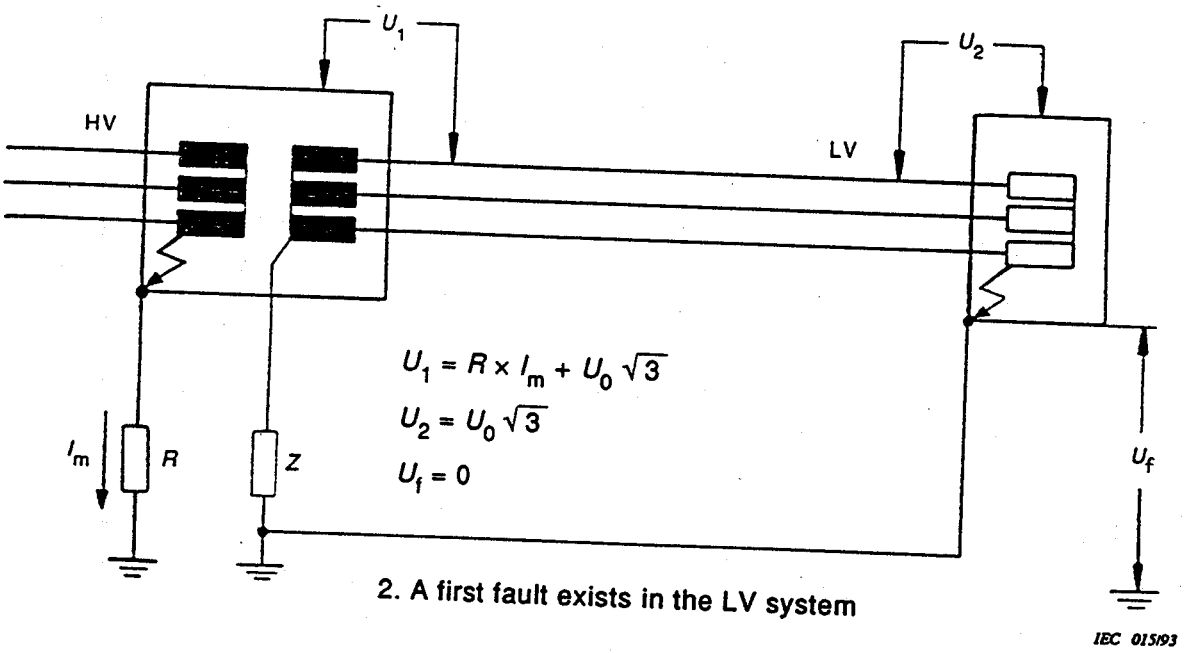


2. A first fault exists in the LV system

Figure 44 G – IT-system, example c2

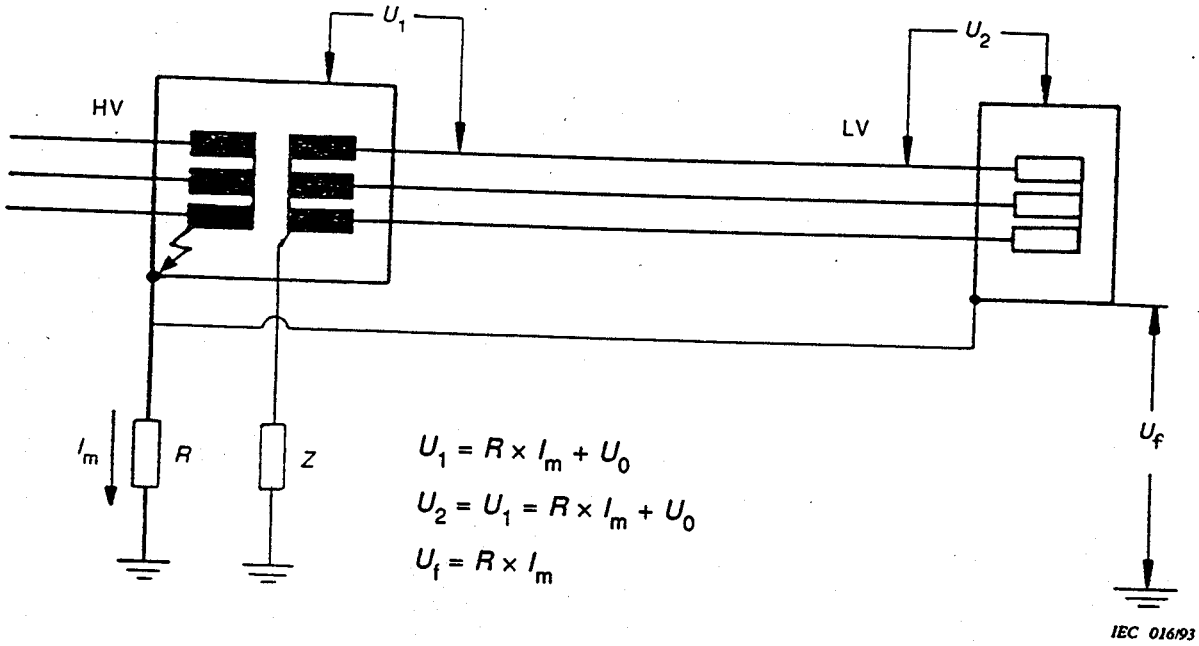


1. No fault exists in the LV system

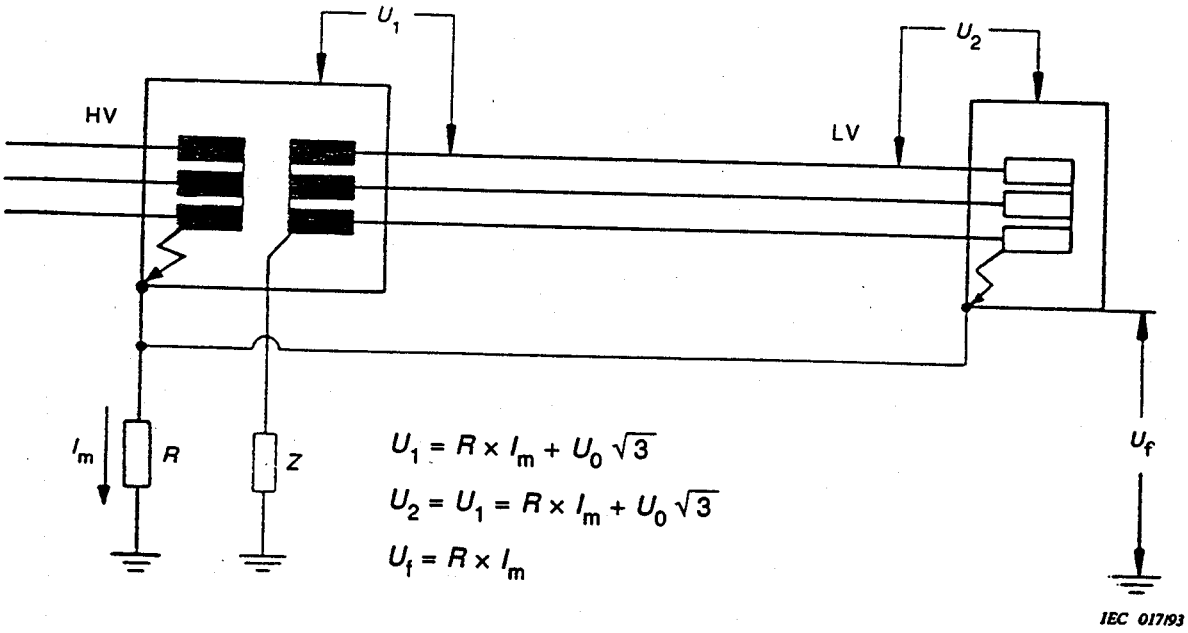


2. A first fault exists in the LV system

Figure 44 H – IT-system, example d

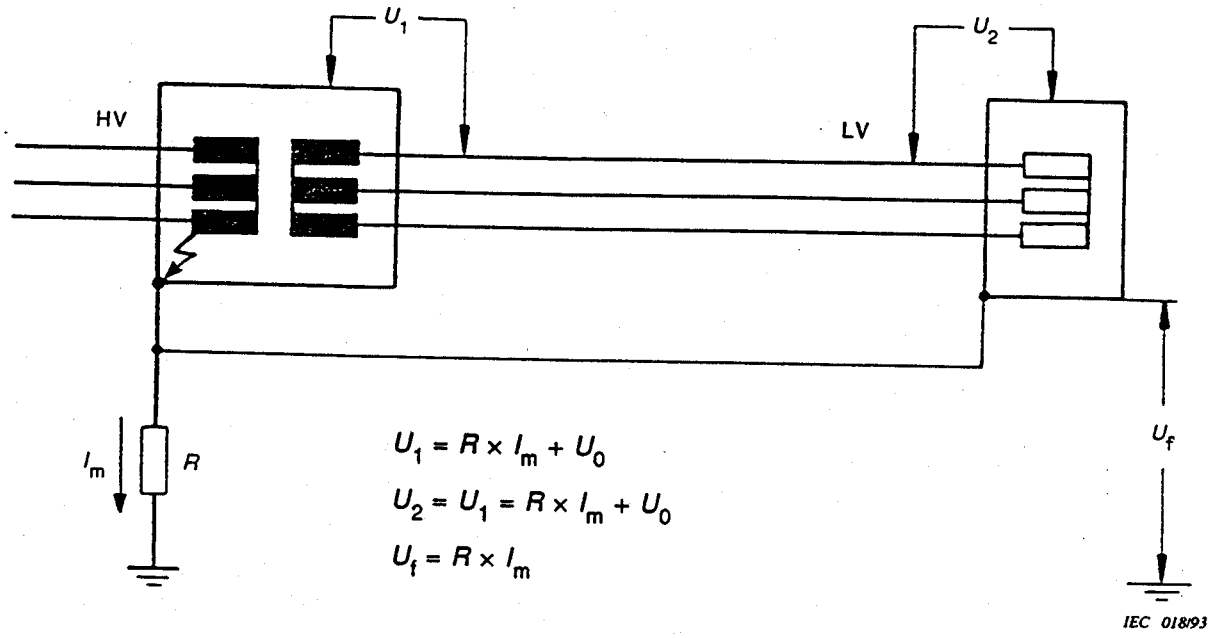


1. No fault exists in the LV system

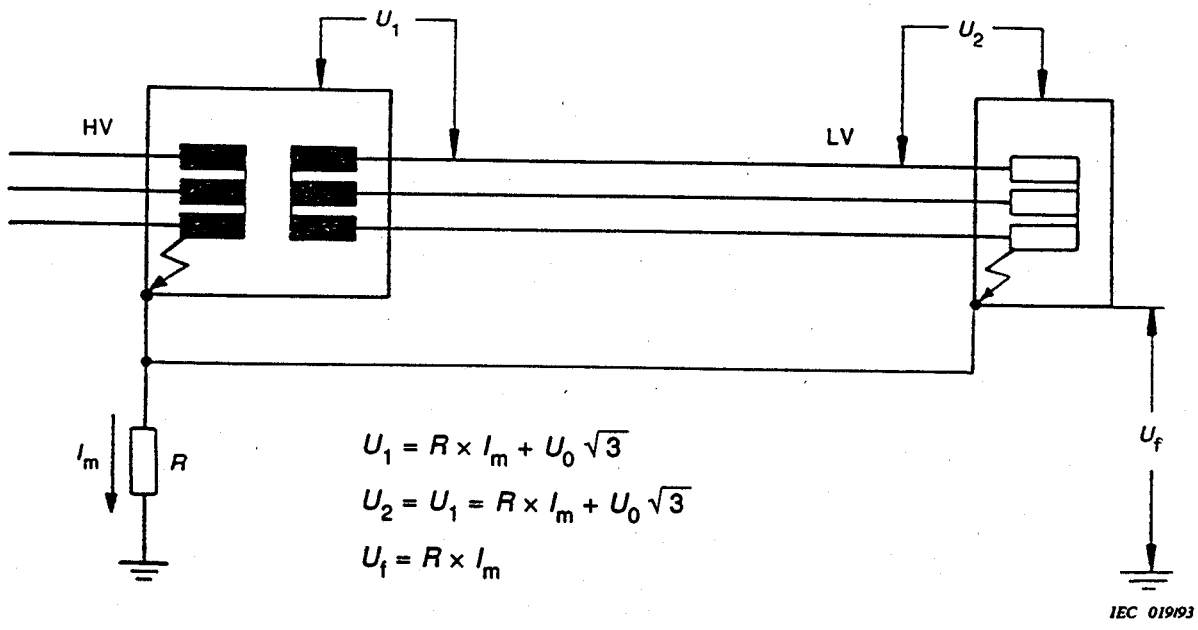


2. A first fault exists in the LV system

Figure 44 J – IT-system, example e1



1. No fault exists in the LV system



2. A first fault exists in the LV system

Figure 44 K – IT-system, example e2

ANNEX A
(informative)

Explanatory notes concerning clause and subclauses 442.1, 442.1.2 and 442.1.3

A.442.1 General

The rules in this section are intended to provide for the safety of persons and equipment in a LV system in the event of an earth-fault in the HV system.

Faults between systems at different voltages refer to those that may occur on the high-voltage side of the sub-station supplying a low-voltage system through a distribution system operating at a higher voltage. Such faults cause a current to flow in the earth electrode to which the exposed-conductive-parts of the sub-station are connected.

The magnitude of the fault-current depends on the fault-loop impedance, i.e. on how the high-voltage neutral is earthed.

The fault-current flowing in the earth electrode of the exposed-conductive-parts of the sub-station causes a rise of the potential with respect to earth of the exposed-conductive-parts of the sub-station whose magnitude is governed by:

- the fault-current magnitude, and
- the resistance of the earth electrode of the exposed-conductive-parts of the sub-station.

The fault-voltage may be as high as several thousand volts and, depending on the earthing systems of the installation, may cause:

- a general rise of the potential of the low-voltage system with respect to earth, which may cause a breakdown in the low-voltage equipment;
- a general rise of the potential of the exposed-conductive-parts of the low-voltage system with respect to earth, which may give rise to fault and touch-voltages.

It usually takes longer to clear a fault in a high-voltage system than in a low-voltage system, because the relays have time delays for discrimination against unwanted tripping on transients. The operating times of the high-voltage switchgear are also longer than for low-voltage switchgear. This means that the resulting duration of the fault-voltage and the corresponding touch-voltage on the exposed-conductive-parts of the low-voltage system may be longer than required by the LV installation rules.

There may also be a risk of breakdown in the low-voltage system of the sub-station or consumer's installation. The operation of protective devices under abnormal conditions of transient recovery voltages may give rise to difficulties in opening the circuit or even failure to do so.

The following fault conditions in the high-voltage system are taken into consideration:

Effectively earthed high-voltage systems

These systems include those systems where the neutral is connected to earth either directly or via a low impedance and where earth faults are cleared in a reasonably short time given by the protective equipment.

No connection of the neutral to earth in the relevant transformer sub-station is considered.

In general, capacitive currents are neglected.

Isolated high-voltage systems

Only single-fault conditions due to a first earth fault between a high-voltage live-part and exposed-conductive-parts of the transformer sub-station are taken into account. This (capacitive) current may or may not be interrupted, depending on its magnitude and the protective system.

High-voltage systems with arc-suppression coils

No arc-suppression coils in the relevant transformer sub-station are considered.

Where an earth fault in the high-voltage system occurs between a high-voltage conductor and the exposed-conductive-parts of the transformer sub-station, only small fault currents occur (residual currents mostly in the order of some tens of amperes). These currents may persist for longer times.

A.442.1.2 *Fault-voltage*

Figure 44 A has been derived from Curve C 1 of IEC 479-1.

When considering the values for the fault-voltage, the following should be taken into account:

a) the low risk of an earth-fault in the HV system,

b) the fact that the touch voltage is always lower than the fault-voltage due to the main equipotential bonding required in 413.1.1.2 of IEC 364-4-41 and the presence of additional earth electrodes at the consumer's installation or elsewhere.

Values given by CCITT: 650 V for 0,2 s and 430 V for automatic disconnection in longer than 0,2 s are slightly in excess of the values in figure 44 A.

A.442.1.3 *Stress-voltage*

The value 1,5 U_n + 750 V equals 0,75 times the lowest repetitive test voltage of low-voltage equipment and allows the rules of this section to be applied to directly earthed high-voltage installations.

Table of the different possibilities for IT-systems

(Taking into account a first fault in the LV installation)
(see 442.4.4 and 442.5.2)

System	Exposed-conductive-parts of LV equipment of the sub-station	Neutral impedance, if any	Exposed-conductive-parts of equipment of the LV installation	U_1	U_2	U_f
a	●	●	●	$U_0\sqrt{3}$	$U_0\sqrt{3}$	$R \times I_m$
b	●	●	0	$U_0\sqrt{3}$	$R \times I_m + U_0\sqrt{3}$	0 *
c **	0	0	0	$R \times I_m + U_0\sqrt{3}$	$U_0\sqrt{3}$	0 *
d	0	●	●	$R \times I_m + U_0\sqrt{3}$	$U_0\sqrt{3}$	0 *
e **	●	0	●	$R \times I_m + U_0\sqrt{3}$	$R \times I_m + U_0\sqrt{3}$	$R \times I_m$

* In fact, U_f is equal to the product of first fault current by the resistance of the earth electrode of the exposed conductive parts ($R_A \times I_d$) which shall be less or equal to U_L.

Further, in systems a, b and d, the capacitive currents which flow through the first fault may increase in certain cases the value of U_f, but this is disregarded.

**In systems c1 and e1, an impedance is installed between the neutral and earth (impedance neutral).

In systems c2 and e2, no impedance is installed between the neutral and earth (isolated neutral).

Figures 44 D to 44 K give the various possibilities of earthing arrangements, with or without a first fault at the consumer's installation.

NORME INTERNATIONALE
INTERNATIONAL STANDARD

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1992

AMENDEMENT 1
AMENDMENT 1

1995-08

Amendement 1

Installations électriques des bâtiments

Partie 4:
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Chapitre 44: Protection contre les surtensions
Section 442 – Protection des installations à basse tension contre les défauts à la terre dans les installations à haute tension

Amendment 1

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Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

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PRICE CODE D

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FOREWORD

This amendment has been prepared by IEC technical committee 64: Electrical installations of buildings.

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

DIS	Report on voting
64/748/DIS	64/795/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

Title of this section of IEC 364-4

Amend the existing title as follows:

Section 442 – Protection of low-voltage installations against temporary overvoltages and faults between high-voltage systems and earth.

Page 9

442.1 General

Add, under the title of this clause, the following note:

NOTE – The following clauses only consider four situations which generally cause the most severe temporary overvoltages such as defined in IEV 604-03-12:
- fault between the high-voltage system(s) and earth. The correspondent subclauses should be read in conjunction with annex A;
- loss of the neutral in a low-voltage TN and TT system (see 442.6);
- accidental earthing of a low-voltage IT system (see 442.7);
- short circuit in the low-voltage installation (see 442.8).

Table 44A

Replace the existing table by the following new table:

Permissible a.c. stress voltage on equipment in low-voltage installations V	Disconnecting time s
U_0 + 250 V	> 5
U_0 + 1 200 V	≤ 5

NOTES

1 In particular cases (e.g. line conductor earthed), where the (highest) nominal voltage of the low-voltage system to earth is not U_0, this voltage shall be specified.

2 The first line of the table relates to systems having long disconnection times, for example inductively earthed high-voltage system. The second line relates to systems having short disconnection times, for example solidly earthed high-voltage systems. Both lines together are relevant design criteria for insulation of low-voltage equipment with regard to temporary overvoltage (see 1.3.7.1 of IEC 664-1).

3 Such temporary a.c. overvoltage is also to be expected in basic, double and reinforced insulation of low-voltage equipment used outside the main equipotential bonding and connected to a TN system (whose neutral conductor is earthed in the transformer substation through the protective earth electrode of the high-voltage system). It is not necessary to expect such overvoltage within the area of main equipotential bonding which is connected to the protective conductor of an TN system at the origin of the installation of the building.

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Add the following new clauses

442.6 Stress voltage in case of loss of the neutral conductor in a TN and TT system

Consideration shall be given to the fact that, if the neutral conductor in a three-phase TN or TT system is interrupted, basic, double and reinforced insulation as well as components rated for the voltage between line and neutral conductors can be temporarily stressed with the line-to-line voltage. The stress voltage can reach up to $U = \sqrt{3}\ U_0$.

442.7 Stress voltage in case of accidental earthing of an IT system

Consideration shall be given to the fact that, if a line conductor of an IT system is earthed accidentally, basic, double and reinforced insulation rated for the voltage between line and neutral conductors as well as components can be temporarily stressed with the line-to-line voltage. The stress voltage can reach up to $U = \sqrt{3}\ U_0$.

442.8 Stress voltage in case of a short circuit between a line conductor and the neutral conductor

Consideration shall be given to the case of a short circuit between a line conductor and the neutral conductor where the stress voltage can reach the value of 1,45 U_0 for a time up to 5 s.

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Delete subclause A.442.1.3.