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Vodilo za določanje prerezov vodnikov in izbiro zaščitnih naprav

Guide for determination of cross-sectional area of conductors and selection of protective devices

Leitfaden für die Festlegung von Leiterquerschnitten und die Auswahl von Schutzeinrichtungen

Guide pour la détermination des sections des conducteurs et choix des dispositifs de protection

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REPORT

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English version

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Leitfaden für die Festlegung von Leiterquerschnitten und die Auswahl von Schutzeinrichtungen

This CENELEC Report has been prepared by SC 64B, Protection against thermal effects, of Technical Committee CENELEC TC 64, Electrical installations of buildings. It was approved by the Technical Committee on 1995-11-29 and endorsed by the CENELEC Technical Board on 1996-10-01.

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CENELEC
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Introduction

The harmonised rules for electrical installations of buildings, HD 384, require calculations for sizing of many components of an electrical installation.

In complex installations long and detailed calculations may be needed. The rules of HD 384 give the basic principles without the details necessary for an accurate application.

Computers with appropriate software enable the applicable rules for the determination of conductor cross-section area and selection of protective devices to be applied readily.

It is important that the results of such software programs are in accordance with the harmonised rules.

Therefore this Guide defines the different reference parameters necessary for the calculation of the cross-sectional area of the conductors and for the selection of the protective devices. It also gives the reference methods for calculation according to the different safety rules defined in the Harmonisation Documents of the series HD 384 .

1 Scope

This Guide applies to low-voltage installations in which the circuits consist of insulated conductors, cables or busbar trunking systems.

It defines the different parameters used for the calculation of the characteristics of electrical wiring systems in order to comply with rules of HD 384.

These rules are mainly the following :

- current-carrying capacities of the conductors,
- characteristics of protective devices in regard to protection against overcurrent,
- verification of thermal stress in conductors due to short-circuit current or fault current,
- protection against indirect contact,
- limitation of voltage drop.

NOTE 1: Mechanical stress in cables during short-circuit is covered by IEC 865.

NOTE 2: In general these calculations concern supply by HV/LV transformer, but they are also applicable to supply by LV/LV transformer.

The parameters defined in this Guide are especially intended to permit the verification of software programs for calculation of cross-sectional area of insulated conductors, cross-sectional area of cables and characteristics for selection of busbar trunking systems in order to check the conformity of the results with HD 384.

2 Reference documents

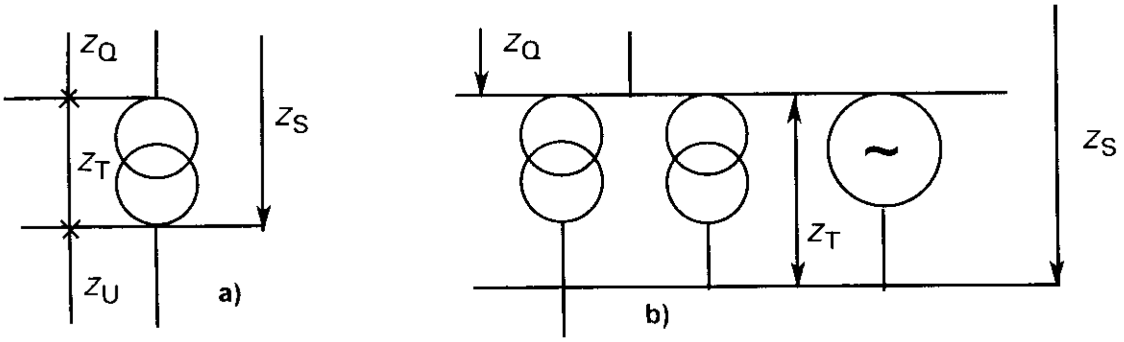
The indications given in this Guide refer to the following CENELEC and IEC documents.

EN 60269-2	Low-voltage fuses -- Part 2: Supplementary requirements for fuses for use by authorized persons (fures mainly for industrial application)
EN 60269-3	Low-voltage fuses -- Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar appliances)
EN 60439-1	Low-voltage switchgear and controlgear assemblies -- Part 1: Type-tested and partially type-tested assemblies (IEC 60439-1:1985, modified)
EN 60439-2	Low-voltage switchgear and controlgear assemblies -- Part 2: Particular rules for busbar trunking systems (busways) (IEC 60439-2:1987 + A1:1991, modified)
EN 60898	Circuit-breakers for overcurrent protection for household and similar installations (IEC 60898 series, modified)
EN 60947-2	Low-voltage switchgear and controlgear -- Part 2: Circuit-breakers
HD 383	Conductors of insulated cables - Guide to the dimensional limits of circular conductors
HD 384	Electrical installations of buildings
HD 384.4.41	Part 4: Protection for safety -- Chapter 41: Protection against electric shock
HD 384.4.43	Part 4: Protection for safety -- Chapter 43: Protection against overcurrent
HD 384.4.473	Part 4: Protection for safety -- Chapter 47: Application of protective measures for safety -- Section 473: Application of protective measures against overcurrents
HD 384.5.52	Part 5: Selection and erection of electrical equipment -- Chapter 52: Wiring systems
HD 384.5.523	Part 5: Selection and erection of electrical equipment -- Chapter 52: Wiring systems Section 523: Current-carrying capacities
HD 384.5.53	Part 5: Selection and erection of electrical equipment -- Chapter 53: Switchgear and controlgear
HD 384.5.54	Part 5: Selection and erection of electrical equipment -- Chapter 54: Earthing arrangements and protective conductors
HD 384.6.61	Part 6: Verification -- Chapter 61: Initial verification
HD 398	Power transformers
HD 581	Application guide for calculation of short-circuit currents in low voltage radial systems (IEC 60781)
IEC 60724	Guide to the short-circuit temperature limits of cables
IEC 60865	Short-circuit current - Calculation of effects
IEC 60909	Short-circuit current calculation in three-phase AC systems.
R064-001	CENELEC report on current-carrying capacities in conductors and cables

3 Symbols

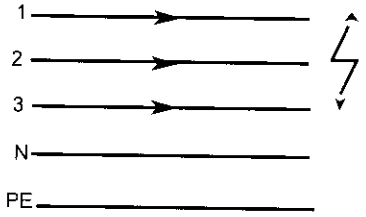
I_B	Design current of the circuit being considered, [A] (IEV 826-05-04)
I_z	Current-carrying capacity of a conductor, [A] (IEV 826-05-05)
I_f	Fault current, [A]
I_{nc}	Rated current of busbar trunking system, at an ambient temperature of 30°C, [A]
I_p	Maximum peak value of three-phase short-circuit current, [kA]
$(I^2{}_0\, t_0)$	Thermal stress capacity of phase, neutral or PE (PEN) conductor given in general for one second, [A².s], (IEV 447-07-17 and EN 60439-2, 4.3)
L_1	Route length, [m], subscript u : upstream subscript d : downstream
L_2	Length of busbar trunking system, [m] subscript u : upstream subscript d : downstream
R_N	Resistance of the neutral conductor upstream of the circuit being considered, $R_N = \sum R_{\text{neutral}}$, [mΩ]
R_{PE}	Resistance of the protective conductor from the main equipotential bonding to the origin of the circuit being considered, $R_{PE} = \sum R_{\text{protective conductor}}$, [mΩ]
R_{PEN}	Resistance of the PEN conductor from the main equipotential bonding to the origin of the circuit being considered, $R_{PEN} = \sum R_{\text{PEN conductor}}$, [mΩ]
R_Q	Resistance upstream of the source, [mΩ]
R_T	Resistance of the source, [mΩ]
$R_{b0\ ph}$	Mean ohmic resistance of BTS per meter, per phase, at 20°C, [mΩ / m]
$R_{b1\ ph}$	Mean ohmic resistance of BTS per meter, per phase, at rated current I_{nc}, at the steady-state operating temperature, [mΩ / m]
R_{b0}	Resistive term of mean phase-phase, phase-neutral or phase-PE (-PEN) BTS loop impedance, at 20°C, [mΩ / m]
R_{b1}	Resistive term of mean phase-phase, phase-neutral or phase-PE (-PEN) BTS loop impedance, at rated current I_{nc}, at the steady-state operating temperature, [mΩ / m]
R_{b2}	Resistive term of mean phase-phase, phase-neutral or phase-PE (-PEN) BTS loop impedance, at the mean temperature between the operating temperature at rated current I_{nc}, and the maximum temperature under short-circuit conditions, [mΩ / m]
R_u	Resistance of the phase conductor upstream of the circuit being considered, $R_u = \sum R_{\text{phase}}$, [mΩ]
S	Cross-sectional area of conductors, [mm²]
S_N	Cross-sectional area of neutral conductor, [mm²]
S_{PE}	Cross-sectional area of protective conductor, [mm²]
S_{PEN}	Cross-sectional area of PEN conductor, [mm²]

S_{kQ} :	Short-circuit power of the high-voltage network, [kVA]
S_{ph}	Cross-sectional area of phase conductor, [mm²]
U_o	Phase to neutral nominal voltage of the installation, [V]
U_n	Phase to phase nominal voltage of the installation, [V]
X_N	Reactance of the neutral conductor upstream of the circuit being considered, $X_N = \sum X_{\text{neutral}}$, [mΩ]
X_{PE}	Reactance of the protective conductor from the main equipotential bonding to the origin of the circuit being considered, $X_{PE} = \sum X_{\text{protective conductor}}$,[mΩ]
X_{PEN}	Reactance of the PEN conductor from the main equipotential bonding to the origin of the circuit being considered, $X_{PEN} = \sum X_{\text{PEN conductor}}$, [mΩ]
X_Q	Reactance upstream of the source, [mΩ]
X_T	Reactance of the source, [mΩ]
X_b	Reactance term of mean phase-phase, phase-neutral or phase-PE (-PEN) BTS loop impedance, [mΩ / m]
$X_{b\ ph}$	Mean reactance of BTS phase conductor, per meter, [mΩ / m]
X_u	Reactance of the phase conductor upstream of the circuit being considered, $X_u = \sum X_{\text{phase}}$, [mΩ]
Z_Q	Impedance upstream of the source, [mΩ] $Z_Q = \sqrt{R_Q^2 + X_Q^2}$
Z_T	Impedance of the source, [mΩ] $Z_T = \sqrt{R_T^2 + X_T^2}$
Z_S	$Z_S = Z_Q + Z_T = \sqrt{R_S^2 + X_S^2}$

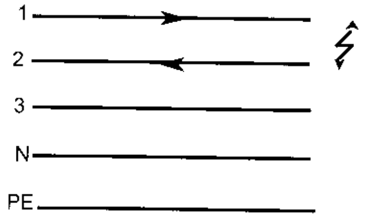


c	Voltage factor
m	no load voltage factor
n_N	Number of neutral conductors in parallel
n_{PE}	Number of protective conductors in parallel
n_{PEN}	Number of PEN conductors in parallel.
n_{ph}	Number of phase conductors in parallel
λ	Linear reactance of conductors, [mΩ / m]
ρ_0	Resistivity of conductors at 20 °C, [mΩ.mm² / m]
ρ_1	Resistivity of conductors at the maximum permissible steady-state operating temperature, [mΩ·mm² / m]
ρ_2	Resistivity of conductors at the mean temperature between steady-state temperature and final short-circuit temperature, [mΩ·mm² / m]
ρ_3	Resistivity of separate PE conductors at the mean temperature between ambient and final short-circuit temperature, [mΩ·mm² / m]

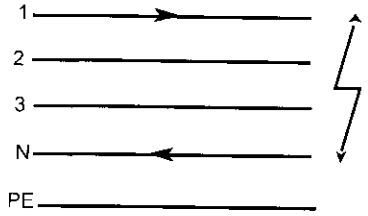
Examples of busbar trunking resistances



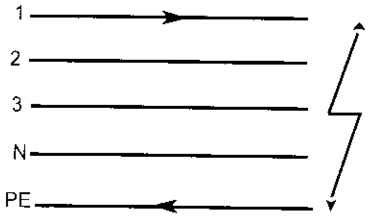
R_{bxph} Three-phase short-circuit



$R_{bxph\text{-}ph}$ Phase to phase short-circuit between ph1 and ph2, note may be between any two phases



$R_{bxph\text{-}N}$ Phase to neutral short-circuit between ph1 and N



$R_{bxph\text{-}PE}$ fault between ph1 and PE

NOTE : The value of x depends on the circuit configuration and on the type of protective device, see table 4b.

4 Parameters

Table 1 : Resistivity at 20°C in accordance with IEC 60909, in mΩ·mm² / m

	Copper	Aluminium
ρ_0	18,51	29,41

Table 2 : Resistivity at various temperatures

	PVC		EPR or XLPE	
	Resistivity	Temperature	Resistivity	Temperature
ρ_0	$1{,}00.\rho_0$	20 °C	$1{,}00.\rho_0$	20 °C
ρ_1	$1{,}20.\rho_0$	70 °C	$1{,}28.\rho_0$	90 °C
ρ_2 $\leq 300\text{mm}^2$	$1{,}38.\rho_0$	$\frac{160+70}{2}=115°\text{C}$	$1{,}60.\rho_0$	$\frac{250+90}{2}=170°\text{C}$
ρ_2 $> 300\text{mm}^2$	$1{,}34.\rho_0$	$\frac{140+70}{2}=105°\text{C}$		
ρ_3 $\leq 300\text{mm}^2$	$1{,}30.\rho_0$	$\frac{160+30}{2}=95°\text{C}$	$1{,}48.\rho_0$	$\frac{250+30}{2}=140°\text{C}$
ρ_3 $> 300\text{mm}^2$	$1{,}26.\rho_0$	$\frac{140+30}{2}=85°\text{C}$		

The above factors are obtained using the following equation :

$$\rho_\theta = \rho_0\,[1 + 0{,}004(\theta - 20)]$$

where θ is the conductor temperature

Table 3 : Linear reactance of conductors (λ) in mΩ / m

	λ
Multicore cables or single core cables in trefoil arrangement	0,08
Flat touching single core cables	0,09
Flat spaced single core cables	0,13

NOTE 1: Values for armored cable should be obtained from the manufacturer.

NOTE 2: The reactance values given are for single-phase systems, they can be used as average values for a three-phase system.

NOTE 3: For spaced single core cables, the axial spacing is assumed to be two times the overall cable diameter.

4.1 Conductor resistances

Conductor resistances per meter at 20°C are given in annex A.

For the calculation set out in this report conductor resistances, for sizes up to 300 mm^2, can be obtained from the following equations :

Phase conductor	**Neutral conductor**	**Protective conductor**		
$R_{c0\,ph} = \dfrac{\rho_0}{S_{ph} \cdot n_{ph}}$	$R_{c0N} = \dfrac{\rho_0}{S_N \cdot n_N}$	$R_{c0\,PE} = \dfrac{\rho_0}{S_{PE} \cdot n_{PE}}$	or $R_{c0PEN} = \dfrac{\rho_0}{S_{PEN} \cdot n_{PEN}}$	$m\Omega / m$
$R_{c1\,ph} = \dfrac{\rho_1}{S_{ph} \cdot n_{ph}}$	$R_{c1\,N} = \dfrac{\rho_1}{S_N \cdot n_N}$	$R_{c1\,PE} = \dfrac{\rho_1}{S_{PE} \cdot n_{PE}}$	or $R_{c1\,PEN} = \dfrac{\rho_1}{S_{PEN} \cdot n_{PEN}}$	$m\Omega / m$
$R_{c2\,ph} = \dfrac{\rho_2}{S_{ph} \cdot n_{ph}}$	$R_{c2\,N} = \dfrac{\rho_2}{S_N \cdot n_N}$	$R_{c2\,PE} = \dfrac{\rho_2}{S_{PE} \cdot n_{PE}}$	or $R_{c2\,PEN} = \dfrac{\rho_2}{S_{PEN} \cdot n_{PEN}}$	$m\Omega / m$
		$R_{c3\,PE} = \dfrac{\rho_3}{S_{PE} \cdot n_{PE}}$		$m\Omega / m$

NOTE: The current sharing has been considered as equal between several conductors in parallel. The current sharing may not be equal between several conductors in parallel of large cross-section e.g greater than 240 mm², hence simple division by the number of conductors may not be suitable (under consideration by IEC/TC 20/ WG 10).

4.2 Conductor reactances

Conductor reactances per meter are obtained from the following equations :

Three-phase or phase to phase	$X_c = \dfrac{\lambda}{n_{ph}}$	$m\Omega / m$
Phase to neutral (or PE or PEN)	$X_{cph} = \dfrac{\lambda}{n_{ph}}$	$m\Omega / m$
	$X_{cN} = \dfrac{\lambda}{n_N}$	$m\Omega / m$
	$X_{cPE} = \dfrac{\lambda}{n_{PE}}$	$m\Omega / m$
	$X_{cPEN} = \dfrac{\lambda}{n_{PEN}}$	$m\Omega / m$

NOTE : For conductors having a cross-sectional area of less than 25 mm², the reactance is much smaller than the resistance and hence it can be ignored for the calculations set out in this report.