



DEMec - Dep. of Mechanical Engineering  
SAIC- Automation, Instrumentation and Control Section  
Master in Mechanical Engineering

## **Electromechanical Systems**

1<sup>st</sup> Year- 2<sup>nd</sup> Semester  
2025-2026

Support documents to TP classes

Electrical Cable Technology and Sizing

Paulo Abreu

**2026 Edition**

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## Electrical Cable Technology and Sizing

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2026

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## Objectives and Industrial Context

### Focus

- **Structural Competence:** Mastery of cable architecture from atomic conductors to environmental sheathing
- **Analytical Rigor:** Execution of IEC 60364-5-52 sizing protocols for industrial reliability
- **Integrated Design:** Evaluating thermal, mechanical, and electromagnetic constraints simultaneously

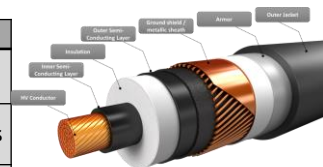
### Industry Relevance

- Mechanical engineers often specify electrical motors and motion systems; understanding the physical limits of the energy transmission medium (the cable) is vital to prevent premature system failure and ensure safety compliance

## Cable Fundamentals Basic Cable Terminology

- **Conductor:** A conductor is a material that allows the flow of electrical current. In practical terms, it is often made of bare copper, aluminum, or silver
- **Wire:** A wire consists of a single conductor encased in a dielectric layer. Wires can come in two forms: solid (rigid) and stranded (flexible)
- **Cable:** A cable consists of two or more insulated conductors bundled together, all encased in a single protective outer layer, known as a sheath or jacket

Term	Composition	Insulation	Typical Use Cases
Conductor	Metal (e.g., copper, aluminum, silver)	No	Core element in wires and cables
Wire	Single conductor (solid or stranded)	Yes	Electrical connections in circuits
Cable	Multiple wires bundled together	Yes	Power distribution, communication systems



[Image ref.](#)

## Cable Fundamentals Basic Cable Terminology

- An **electrical cable** is an assembly of one or more conductors (wires), usually enclosed in an insulating sheath, designed to carry electrical current from one point to another
- Cables vary in structure depending on the type of signal (power, control, or data), the environment in which they're used, and the performance requirements

Each cable is built with multiple layers, each serving a specific function:

- **Conductor**: The core component that carries electric current. Usually made of copper or aluminum, either solid or stranded
- **Insulation**: Surrounds the conductor to prevent electrical contact. Common materials: PVC, XLPE, TPE, PTFE
- **Shielding (Optional)**: Protects against electromagnetic interference (EMI). Types include foil, braid, or spiral shields
- **Sheath / Jacket**: The outermost layer that protects against mechanical, chemical, and environmental damage

## Cable Fundamentals Basic Cable Terminology

### Wire Core Types

- **Solid Core Wire**: A single, thick conductor. Offers better mechanical strength but less flexibility
- **Stranded Core Wire**: Multiple thin wires twisted together. Provides flexibility, commonly used in dynamic applications

PVC insulated solid wire



PVC insulated multistrand Wire

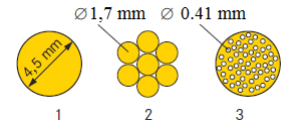
## Cable Fundamentals Basic Cable Terminology

### Wire Size

- **AWG (American Wire Gauge):** Standard for wire size in the U.S.
- **CSA (Cross-Sectional Area):** Measured in mm<sup>2</sup>, commonly used in Europe

### Alternatives to a wire with a 16 mm<sup>2</sup> section conductor

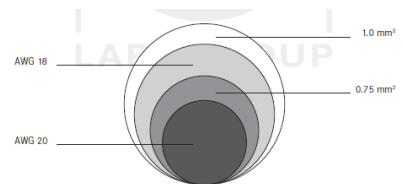
- 4.5 mm diameter single solid conductor
- Multi-wire strand (7 x 1.7 mm)
- Super fine wire strand (122 x 0.41 mm)



### Conversion AWG to CSA (metric)

The lower the AWG number,  
 the thicker the wire!

AWG to Metric Conversion			
AWG	MM <sup>2</sup>	AWG	MM <sup>2</sup>
30	0.05	6	16
28	0.08	4	25
26	0.14	2	35
24	0.25	1	50
22	0.34	1/0	55
21	0.38	2/0	70



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## Cable Fundamentals Conductor Metallurgy & Conductivity

Material	Conductivity (% IACS)	Mass Density (kg/m <sup>3</sup> )	Primary Industrial Use Case
Silver (Ag)	105%	10,490	Precision aerospace and RF systems
Copper (Cu)	100%	8,890	Standard industrial automation and motors
Aluminum (Al)	61%	2,700	Power distribution (high strength-to-weight)

**IACS percentage** stands for **International Annealed Copper Standard**. It is a comparative unit of measure used to express the electrical conductivity of a material relative to a universally recognized standard for pure copper

### Material Design Implication

Necessary to account for the skin effect in AC applications and the thermal expansion coefficients when mating dissimilar metals (e.g., Al cables to Cu terminals). Note that joining dissimilar metals (like aluminum cables to copper terminal blocks) causes galvanic corrosion. In these cases, it is necessary to use specialized bimetallic lugs to prevent connection failures.

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## Cable Construction Insulation and sheathing materials

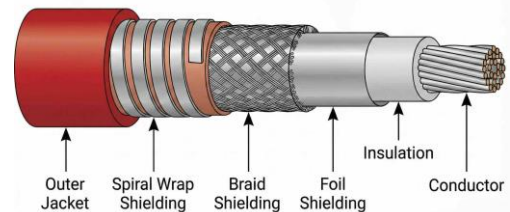
Effective **Electromagnetic Interference (EMI)** mitigation requires specific shielding geometries:

- **Foil Shield:** 100% coverage, static protection.
- **Braid Shield:** Mechanical strength, low-frequency protection.
- **Spiral Shield:** Maximum flexibility for high-duty cycles.

**Concept:** Low Transfer Impedance ( $Z_T$ ) is the hallmark of superior Electromagnetic Compatibility (EMC) performance

Note:

Transfer Impedance ( $Z_T$ ) is an intrinsic measurement of a cable shield's effectiveness. It quantifies how much a shielding layer allows an internal high-frequency current to leak outside the cable as an external voltage (causing emissions), or conversely, how much an external noise current induces an internal noise voltage onto the sensitive inner signal wires (causing susceptibility)



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## Cable Construction Insulation and sheathing materials

- **Insulation Layer:** surrounds each conductor to prevent short circuits and leakage
  - Common Insulation Materials:
    - PVC (Polyvinyl Chloride): cost-effective, good for general use, flame retardant, thermal limit: 70°C
    - XLPE (Cross-Linked Polyethylene): high temperature resistance (90°), High dielectric strength and low dielectric loss, and high mechanical strength
    - TPE (Thermoplastic Elastomer), PUR (Polyurethane): flexible and abrasion-resistant, ideal for dynamic applications
    - PTFE, FEP (Fluoropolymers): high-performance, resistant to chemicals and extreme temperatures
- **Sheath (Jacket) Layer:** the outermost layer that protects the cable from mechanical, chemical, and environmental damage
  - Typical Sheathing Materials:
    - PVC: good all-purpose material, affordable
    - PUR: durable, oil- and chemical-resistant, flexible
    - TPE: excellent for robotic and outdoor applications
    - Rubber or Elastomers: used in flexible or heavy-duty industrial cables

**Relevant properties: electrical isolation, flexibility, UV resistance, resistance to oils or fuels, heat resistance, chemical resistance, mechanical, low flammability, good temperature stability, abrasion-proof,**

**The choice of material dictates the cable's Permissible Operating Temperature, relevant for sizing**

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## Cable Construction Shielding types

### ■ Foil Shielding

- Made of aluminum or polyester-laminated foil
- Provides 100% coverage against electrostatic noise
- Lightweight and flexible
- Common in: Data and signal cables (e.g., Ethernet, RS-485)



### ■ Braid Shielding

- Made from woven copper or aluminum wires
- Offers good mechanical strength and EMI protection
- Not 100% coverage but effective for low-frequency noise
- Used in: audio, power control, VFD cables



### ■ Spiral (Helical) Shielding

- Consists of wire wrapped in a spiral pattern around conductors
- Highly flexible, ideal for cables subject to frequent movement
- Easier to terminate than braid but less coverage

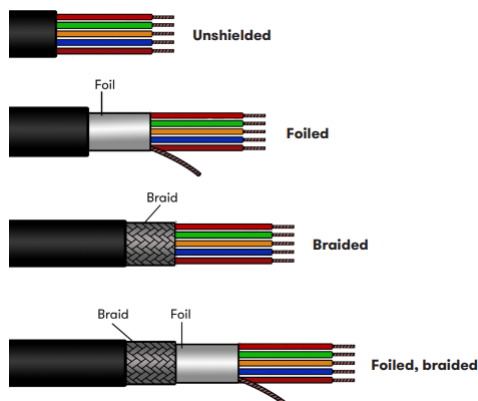


### ■ Foil + Braid Combination

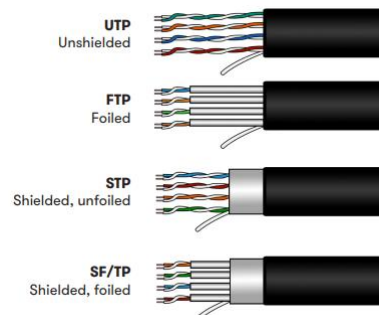
- Combines full coverage of foil with mechanical strength of braid
- Provides excellent protection across a wide frequency range
- Ideal for: Industrial automation, motion control, and communication systems



## Cable Construction Shielding types



### Twisted pair (TP) screening



## Cable Construction Mechanical Characteristics

Cables routed within automated machinery are structural elements that experience complex, continuous mechanical loads. Designing for these systems requires analyzing four main stress profiles:

1. **Bending Stress:** Occurs when a cable moves through a curved path. This subjects the outer layers to tensile forces and the inner layers to compression
2. **Torsion:** The twisting of a cable along its longitudinal axis. This creates high shear stresses across all internal layers and is common in multi-axis robotic joints
3. **Tensile Strain:** The axial pulling force applied to a cable during installation or through vertical hanging suspensions
4. **Abrasion:** Mechanical wear caused by the cable rubbing against guide enclosures, structural surfaces, or adjacent cables within a bundle

## Cable Construction Mechanical Characteristics

### Typical Mechanical efforts on a cable



Torsion



Bending



Folding

- **Torsion Resistance:** refers to the ability of a cable to withstand twisting along its axis
  - **Influenced by**
    - Stranding design of conductors (ultra-fine wires), Reinforcement with fillers or special jackets, and Symmetry of cable geometry
  - **Application relevance**
    - Vital in rotating or swiveling applications, such as robotic joints, machine tools, wind turbines, and elevator loops

## Cable Construction Mechanical Characteristics

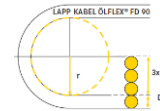
**Bending Resistance:** a measure of how often and tightly a cable can be bent before failure

- Influenced by
  - Core material, Insulation and jacket Materials, and Shielding
- Application relevance
  - Essential in tight-space installations, mobile equipment, and energy chains
  - Important for minimizing downtime due to cable wear and ensuring reliable signal/power transmission

**Bending radius:** the smallest radius a cable can be bent without damage.

Standard values are between  $1.5 \times D$  and  $30 \times D$ , depending on the type of cable construction and standardization.  $D$  is the outside diameter of the cable.

- Influenced by
  - Cable type (solid or stranded), Sheath and insulation flexibility, and Application (static or dynamic)
- Application relevance (Examples)
  - Static Installation:  $4 \times D$
  - Continuous Motion (flexible cable):  $7.5 \times D$
  - High-Flex Robots cables:  $10 \times D +$  (Torsion-rated)



## Cable Construction Mechanical Characteristics

### Mechanical Stress and Strain

- Influenced by
  - Pulling during installation (tensile stress), Vibration, and movement during operation
- Application Relevance
  - Use strain reliefs, cable glands, and cable carriers to minimize mechanical load and prevent premature wear or failure

### Abrasion Resistance

- Influenced by
  - Rubbing against surfaces or other cables: when cables come into contact with surfaces or other cables, abrasion can occur
  - Movement in cable tracks: cables moving within tracks are subject to wear and tear
- Application relevance
  - High abrasion resistance in applications using moving cables in conveyors, mobile equipment

## Cable Tracking Systems: Design Rules for Drag Chains

Cable drag chains (or power tracks) protect and guide cables connected to moving machine components. To prevent premature wear and ensure reliable operation, engineers must follow specific layout guidelines:

- **Clearance Allowances:** The internal cross-sectional area of the drag chain must include a 10% to 15% safety clearance around all enclosed cables to prevent pinching or binding during movement
- **Weight Distribution:** Cables must be distributed symmetrically within the chain based on their weight and outer diameter. Heavy power cables should be placed on the outer edges, with lighter data and signal lines positioned toward the center to balance driving forces and minimize twisting
- **Internal Separation:** Vertical and horizontal dividers should be used to isolate different cable types. This prevents cables from stacking, twisting around one another, or rubbing together during operation
- **Fixation Boundaries:** Cables must be secured using strain-relief clamps only at the stationary and moving ends of the drag chain. The length of the cable within the loop must remain free to move lengthwise without tension to accommodate the mechanical travel of the track

## Cable Fundamentals Basic Cable Terminology

- **Nominal current (Catalog Ampacity,  $I_0$ )**

The "nominal current" of a cable refers to its base, uncorrected current-carrying capacity as stated in a manufacturer's catalog or a standardization table (like IEC 60364-5-52). It is the maximum continuous current the cable can safely carry under a highly specific, idealized set of reference conditions, without the cable being damaged, not exceeding its maximum operating temperature

- **Ampacity of a Cable (Effective Ampacity  $I_z$ )**

The true ampacity, short form of "ampere capacity" (or effective current-carrying capacity), is the actual, calculated maximum current the cable can handle once installed in its final physical environment. It takes the cable's nominal baseline current ( $I_0$ ) and penalizes or rewards it mathematically based on real-world thermal physics. Because cables generate heat ( $I^2R$ ), their ability to dissipate that heat dictates their actual safety limit.

$$I_z = I_0 \cdot K_1 \cdot K_2 \cdot K_3 \dots$$

Where  $K_i$  represents the discrete derating correction factors for temperature, bundling, and installation environment

## Cable Fundamentals Environmental Characteristics

### UV (Ultraviolet) Radiation Resistance

- UV rays can degrade many plastics over time. Outdoor cables must be UV-stabilized (e.g., black PVC, PUR, or special UV-resistant compounds)

### Chemical Resistance

- Resistance to acids, alkalis, solvents, and fuels is critical in chemical plants, factories, and automotive environments. TPE, PUR, and fluoropolymers (PTFE, FEP) offer excellent chemical resistance

### Oil and Grease Resistance

- Cables used in machinery and industrial automation are often exposed to lubricants and coolants. PUR sheathing is preferred due to its oil resistance and mechanical durability

### Temperature Resistance: Each insulation material has a temperature operating range

- PVC: ~ -5 °C to +70 °C
- XLPE: ~ -40 °C to +90 °C or higher
- PTFE/FEP: up to +200 °C

## Cable Fundamentals Cable Classification by Structure

Cables are classified by their internal core structure to match specific industrial power and signal distribution needs:

- **Single-Core Cables:** Contain a single insulated conductor. They are typically used for high-current power distribution where large cross-sections are required, as separate lines are easier to route and dissipate heat more effectively than a single thick multi-core assembly
- **Multi-Core Cables:** Combine multiple insulated wires within a single protective outer jacket. This configuration simplifies installation for multi-phase power systems and control circuits
- **Coaxial Cables:** Built with a central conductor surrounded by a dielectric insulator, a uniform metallic shield, and an outer protective jacket. This concentric geometry maintains a precise, consistent electrical impedance, making it ideal for high-frequency signal delivery and video transmission
- **Twisted-Pair Cables:** Feature pairs of insulated conductors twisted together along their length. This twisting ensures that external electromagnetic noise affects both conductors equally. Differential signaling receivers can then filter out this common-mode noise, significantly reducing crosstalk and interference in communication links like Ethernet and CAN bus networks

## Cable Fundamentals Types of Cables by Application

### Cable Classification by Application

- **Power cables:** for transmitting electrical energy (e.g., from a power source to a motor)
- **Control and signal cables:** for transmitting control signals between equipment
- **Data cables:** for communication (e.g., Ethernet, CAN, Fieldbus)
  - Bus cables
  - Fiber optic cables
  - Coaxial cables
- **Special cables**
  - Servo motor feedback cables
  - Robotic cables
  - Photovoltaic (solar) cables
  - Submarine cables

Modern systems increasingly use "hybrid cables." These combine power conductors and digital feedback lines within a single outer jacket to reduce installation complexity, save space, and lower overall system weight

## Types of Cables by Application from IGUS



### Control cables

Minimum Bend Radius 4xd  
 Insulation material: PVC, PUR or TPE



### Data cables

Minimum Bend Radius 10xd  
 Insulation material: PVC, PUR or TPE



### Servo motor feedback cables

Minimum Bend Radius 7,5xd  
 Special shield with optimized braid  
 Insulation material : PVC or PUR



### Motor cables

Suitable for Variable Frequency Drive (VFD)



### Servo power cables

Minimum Bend Radius 5xd  
 Insulation material: PVC or TPE



### Bus cables

Minimum Bend Radius 10xd  
 Insulation material: TPE



### Fiber optic cables (FOC)

Minimum Bend Radius 5xd  
 Insulation material: PUR or TPE

## Cable Sizing and Selection Criteria

Multiple parameters influence the choice of an electrical cable

- **Application**
  - Power cable
  - Signal cable
  - Data cable
- **Application environment and installation**
  - Temperature, humidity, presence of contaminating elements (oils, corrosive materials), solar radiation, flames
  - Type of installation (underground, gutter, air, ...)
- **Cable type**
  - Single-core cable
  - Multi-core cable
  - Coaxial cable
- **Electrical characteristics**
  - Voltage
  - Current
  - Electrical resistance
- **Mechanical characteristics**
  - Bending capacity
  - Bending radius
  - Weight
  - Corrosion, flame resistance
- **Physical characteristics**
  - Conductive material
  - Insulating material
  - Shield

## Cable Sizing and Selection Criteria

### Cable Sizing Regulatory Guidelines

- **Europe:** IEC 60364, in particular [IEC 60364-5-52](#), with cable sizes specified in square millimeters (mm<sup>2</sup>)
- **USA:** NEC Standards, providing detailed guidelines for cable sizing, including tables for current-carrying capacities, voltage drop calculations, and installation methods, with cable sizes specified using the American Wire Gauge (AWG)

### Cable Sizing Fundamentals using IEC 60364-5-52

- Application and type of cable
- Application environment and installation methods
- Current carrying capacity based on installation methods
- Correction factors and derating
- Voltage drop and short-circuit current rating

### Installation Methods (IEC 60364-5-52 Reference Methods)

- The IEC 60364-5-52 standard provides guidelines for selecting and installing wiring systems. It includes various installation methods, such as direct burial, conduit, and tray installations, each with specific requirements for current-carrying capacity and protection

## Cable Sizing and Selection Criteria

Sizing an electrical cable is a thermodynamic optimization problem bounded by three strict electrical and safety design criteria. The finalized cross-sectional area must satisfy the most restrictive boundary condition among them:

1. **Continuous Thermal Capacity (Ampacity & Derating):** The steady-state heat generated by internal resistance ( $P = I^2R$ ) must not exceed the environment's heat dissipation rate at the insulation's maximum operating temperature. Baseline current-carrying capacities (per IEC 60364-5-52) must be adjusted using derating factors ( $K_i$ ) for ambient temperature, cable grouping/bundling, and installation topology.
2. **Voltage Drop Limitation:** To maintain equipment functionality, cumulative voltage reduction along the route length—driven by conductor impedance and current draw—must not exceed regulatory limits (typically 3% to 5%), especially during high-current transient events like motor startups.
3. **Adiabatic Short-Circuit Limits:** During rapid, high-magnitude electrical faults, the cable operates as a closed thermodynamic system where all energy ( $I^2t$ ) is absorbed entirely by the metallic core. The conductor cross-section must be large enough to survive this intense thermal spike before upstream protective devices clear the fault. **So, the cable must be sized to handle the maximum short-circuit current for a specified duration without damage**

## Cable Sizing Current-Carrying Capacity and Derating Factors

The effective current capacity ( $I_z$ ) is derived from the base ampacity ( $I_0$ ) and environmental correction factors:

$$I_z = I_0 \cdot K_1 \cdot K_2 \cdot K_3$$

- $K_1$ : Ambient Temperature  
Accounts for air or soil heat dissipation variance
- $K_2$ : Grouping  
Mutual heating of cables in a single tray or duct
- $K_3$ : Installation method  
Based on IEC 60364-5-52 Reference Methods

**Cable sizing is not just a lookup table; it is a thermal management problem bounded by voltage drop and short-circuit dynamics**

## Current carrying capacity - IEC 60364-5-52

The standard IEC 60364-5-52 defines ten (10) different Reference Methods of installation as follows:

- Reference method A1, insulated conductors in conduit in a thermally insulated wall
- Reference method A2, multi-core cable in conduit in a thermally insulated wall
- Reference method B1, insulated conductors in conduit on a wooden or masonry wall
- Reference method B2, multi-core cable in conduit on a wooden or masonry wall
- Reference method C, single-core or multi-core cable on a wooden or masonry wall
- Reference method D1, multi-core cable in ducts in the ground
- Reference method D2, multi-core cables designed to be buried directly in the ground
- Reference method E, multicore cable in free air
- Reference method F, single-core cables, touching in free air
- Reference method G, single-core cables, spaced in free air

TopCable, [Methods of Installation and current-carrying capacities based on IEC 60364-5-52 Ed.3,](#)

- For each reference method, the current-carrying capacity of a conductor is a function of cable construction properties and load phases
  - Conductor material e.g. copper or aluminum
  - Conductor insulation e.g. PVC or XLPE, Mineral
  - Number of loaded conductors e.g. two or three

## Current carrying capacity - IEC 60364-5-52

For each combination of the above cable/load properties, Annex B of the standard, presents tables with **Current-carrying capacity** for specific conductor cross-sectional area (expressed in mm<sup>2</sup>)

Exert of table:

Table B.52.10 – Current-carrying capacities in amperes for installation methods E, F and G of Table B.52.1 – PVC insulation, copper conductors – Conductor temperature: 70 °C, reference ambient temperature: 30 °C

Nominal cross-sectional area of conductor mm <sup>2</sup>	Installation methods of Table B.52.1							
	Multi-core cables				Single-core cables			
	Two loaded conductors	Three loaded conductors	Two loaded conductors touching	Three loaded conductors trefoil	Three loaded conductors, flat			
	Method E	Method E	Method F	Method F	Touching	Spaced		
					Horizontal	Vertical		
	Method E	Method E	Method F	Method F	Method F	Method G	Method G	
	1	2	3	4	5	6	7	8
1,5	22	18,5	–	–	–	–	–	–
2,5	30	25	–	–	–	–	–	–
4	40	34	–	–	–	–	–	–
6	51	43	–	–	–	–	–	–
10	70	60	–	–	–	–	–	–
16	94	80	–	–	–	–	–	–
25	119	101	131	110	114	146	130	–
35	148	126	162	137	143	181	162	–

## Current carrying capacity - IEC 60364-5-52

The reference values are then adjusted (**derated**), taking into consideration **Correction factors** and other **Reduction factors** given in other tables

Table B.52.15 – Correction factors for ambient ground temperatures other than 20 °C to be applied to the current-carrying capacities for cables in ducts in the ground

Ground temperature °C	Insulation	
	PVC	XLPE and EPR
10	1,10	1,07
15	1,05	1,04
20	1,00	1,00
25	0,95	0,96

Table B.52.14 – Correction factor for ambient air temperatures other than 30 °C to be applied to the current-carrying capacities for cables in the air

Ambient temperature* °C	Insulation			
	PVC	XLPE and EPR	Minera <sup>®</sup>	Bare not exposed to touch 165 °C
10	1,22	1,15	1,26	1,14
15	1,17	1,12	1,20	1,11
20	1,12	1,08	1,14	1,07
25	1,06	1,04	1,07	1,04

Table B.52.16 – Correction factors for cables buried direct in the ground or in buried ducts for soil thermal resistivities other than 2,5 K · m/W to be applied to the current-carrying capacities for reference method D

Thermal resistivity, K · m/W	0,5	0,7	1	1,5	2	2,5	3
Correction factor for cables in buried ducts	1,28	1,20	1,18	1,1	1,05	1	0,96
Correction factor for direct buried cables	1,88	1,62	1,5	1,28	1,12	1	0,90

Table B.52.17 – Reduction factors for one circuit or one multi-core cable or for a group of more than one circuit, or more than one multi-core cable, to be used with current-carrying capacities of Tables B.52.2 to B.52.13

Item	Arrangement (positive factor)	Number of circuits or multi-core cables										To be used with current-carrying capacities reference		
		1	2	3	4	5	6	7	8	9	10		16	20
1	Bunched in air, on a surface, embedded or enclosed	1,00	0,90	0,70	0,60	0,50	0,57	0,54	0,52	0,50	0,45	0,41	0,38	B.52.2 to B.52.13 Methods A to F
2	Single layer on wall, floor or underground cable tray systems	1,00	0,88	0,78	0,78	0,72	0,72	0,72	0,71	0,70				
3	Single layer fixed directly under a section ceiling	0,95	0,91	0,72	0,68	0,68	0,64	0,63	0,62	0,61				No further reduction factor for more than nine circuits or multi-core cables
4	Single layer on a perforated horizontal or vertical cable tray system	1,00	0,88	0,82	0,77	0,76	0,73	0,73	0,72	0,72				
5	Single layer on cable ladder systems or cable etc.	1,00	0,87	0,82	0,80	0,80	0,79	0,79	0,79	0,79				B.52.2 to B.52.13 Methods C and F

## Cable Sizing Voltage Drop Calculation

- **Three-phase circuit** 
$$\Delta V = \frac{\sqrt{3} \cdot I \cdot (R_c \cdot \cos\varphi + X_c \cdot \sin\varphi) \cdot L}{1000}$$
- **Single-phase circuit** 
$$\Delta V = \frac{2 \cdot I \cdot (R_c \cdot \cos\varphi + X_c \cdot \sin\varphi) \cdot L}{1000}$$
- **DC circuit** 
$$\Delta V = \frac{2 \cdot I \cdot R \cdot L}{1000}$$

To ensure device functionality and efficiency, the cumulative voltage drop must typically remain under 3-5%.

With

$\Delta V$ voltage drop [V]	$X_c$ reactance of conductor cable [ohm/Km]
$I$ rated current [A]	$\cos\varphi$ power factor
$R_c$ resistance of the conductor cable [ohm/Km]	$L$ length of the conductor cable [m]

## Cable Sizing Short Circuit Calculation

During a rapid, high-magnitude short-circuit fault (lasting milliseconds to a few seconds), there is insufficient time for heat to conduct through the insulation and dissipate. The cable behaves as an adiabatic system: all electrical fault energy ( $I^2t$ ) is absorbed entirely by the metallic conductor core, causing an immediate, sharp temperature spike that the conductor cross-section must be sized to withstand before protective devices trip.

The **short-circuit current rating** (SCCR) is the maximum short-circuit current a cable, component or assembly can safely withstand when protected by a specific overcurrent protective device (fuse, circuit breaker, ...) or for a specified time allowable.

- The allowable minimum safe cross section that can sustain the short-circuit current rating can be calculated using the following equation:

$$S_{min} = \frac{I_{sc} \cdot \sqrt{t}}{K}$$

$I_{sc}$  RMS short-circuit fault current [kA]

$K$  adiabatic material factor, dependent on type insulation and final temperature reached for short-circuit

$K = 143$  for cooper conductor, XLPE or EPR insulation

$K = 115$  for cooper conductor, PVC insulation

$K = 94$  for aluminum conductor XLPE or EPR insulation

$S_{min}$  minimum safe cross section [mm<sup>2</sup>]

$t$  fault duration time [s]

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## Cable Sizing Example Step-by-Step (I)

### Input data

- Cable for motor 400V, 37 kW, three-phase motor, power factor = 0.88 ,  $\eta = 0.94$

### Selected Cable and installation requirements

- Multi-core cable type: Cu/PVC/GSWB/PVC, 3C+E, 0.6/1kV
- Ambient temperature: 40° C
- Cable installation: above ground, in duct, single layer, together with 2 other cables (IEC Reference method B2)
- Cable length 10 m
- The upstream protection can experience a maximum short-circuit fault current ( $I_{sc}$ ) of 6000 A with a breaker clearing time ( $t$ ) of 0.1s

### Calculations (using reference method from IEC 60364-5-52)

#### 0. Motor load current

use the exact full-load current (FLA) value printed on the physical motor nameplate, or calculate

$$I = \frac{P}{\eta \cdot \sqrt{3} \cdot V \cdot \cos \varphi} = \frac{37000}{0.94 \cdot \sqrt{3} \cdot 400 \cdot 0.88} = 64.6 \text{ A}$$

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## Cable Sizing Example Step-by-Step (II)

### 1. Cable selection based on reference current

- Ambient temperature correction factor (PVC cable) of 0.87
- The correction factor of a cable arranged in a single layer in a duct, with a total of 3 cables is 0.82
- Total **derating factor** = 0.87 x 0.82 = 0.7134
- Note that 16 mm<sup>2</sup> and 25 mm<sup>2</sup> and 35 mm<sup>2</sup> conductors have a base current carrying capacity of 80A and 101A and 126A, respectively

Section (mm <sup>2</sup> )	Base Capacity (I <sub>0</sub> )	Corrected (I <sub>2</sub> )	Verdict
16	80 A	57.1 A	Insufficient
25	101 A	72.1 A	Selected
35	126 A	89.9 A	Over-engineered

- Since the motor consumes 64.6 A, the 25 mm<sup>2</sup> conductor cable must be selected

## Cable Sizing Example Step-by-Step (III)

### 2. Voltage Drop Verification

For 10 m run at 25 mm<sup>2</sup>, (a 25 mm<sup>2</sup> cable has an R<sub>c</sub> of 0.884 Ω/km and an X<sub>c</sub> of 0.0895 Ω/km)

$$\Delta V = \frac{\sqrt{3} \cdot I \cdot (R_c \cdot \cos\phi + X_c \cdot \sin\phi) \cdot L}{1000} = \frac{\sqrt{3} \cdot 59,3 \cdot (0,884 \cdot 0,88 + 0,0895 \cdot 0,475) \cdot 10}{1000} = 0,92 \text{ V}$$

$$(0,92/400 = 0,23\%) \ll 3\% \quad \text{Fully compliant}$$

### 3. Cable verification for short circuit current

Assuming

- Selected Cable Size (S): 25 mm<sup>2</sup>
- Copper conductor, XLPE insulated
- Adiabatic Constant (K): 143 (From IEC 60364-5-54 for a Copper conductor with 90°C XLPE insulation)
- Prospective Short-Circuit Current (I<sub>sc</sub>): assume a severe, standard fault current near the main panel terminal of 6 kA
- Breaker Tripping Time (t): assume a standard industrial molded case circuit breaker (MCCB) protecting the motor feeder, operating in its instantaneous magnetic tripping zone with a total clearing time of 0.1 seconds

$$\text{Verification: } S_{min} = \frac{I_{sc} \cdot \sqrt{t}}{K} = \frac{6000}{143} \sqrt{0,1} = 13,3 \text{ mm}^2 \ll 25 \text{ mm}^2 \quad \text{Selected cable PASS}$$

## Connectivity and EMC Termination

Use professional assembly

A cable design is only as reliable as its termination points. Lugs provide the mechanical and electrical interface between cable conductors and system busbars or terminal blocks.

- **Ring Lugs:** Provide a secure, circular connection that prevents the wire from slipping off the terminal stud, making them ideal for high-vibration environments.
- **Fork (U-Shape) Lugs:** Feature an open design that allows for fast installation and maintenance without completely removing the terminal screw. They are restricted to low-voltage, low-vibration control circuits.
- **Pin Lugs:** Cylindrical terminals used to neaten and terminate stranded wire ends into compression-screw terminal blocks.
- **Bimetallic Lugs:** Feature an aluminum barrel friction-welded to a copper ring face. These specialized components are required when connecting aluminum cables to copper busbars to prevent galvanic corrosion and loose connections caused by unequal thermal expansion.
- **Shield Brushes:** For low-impedance 360° EMC grounding
- **Ferrites:** Suppression of high-frequency noise



## Cable Accessories, Assembly, and Tools

- **Connectors**
  - Signal connectors
  - Power connectors

[Iigus M23 Signal connectors](#)

IGUS [M23 Power connectors](#)

- **Glands**



- **Crimping tools**



- **Cable marking**
- **Cable sleeving**
- **Cable carriers (*esteira porta-cabos*)**
  - Fixed
  - Flexible



[ELANDcables accessories](#)  
[LAPP cable marking systems](#)  
[LAPP connectors](#)  
[Harting connectors](#)  
[Iigus cable carriers](#)

## Special Care in Cable Assembly

- **Continuity of the earth/braid line:** Shielding braids must maintain electrical continuity across all intermediate junction boxes and connection points to ensure a continuous path to ground.
- **Termination of cable:** Secure the cable jacket rigidly before the termination block
- **Terminal soldering/crimping:** All terminal crimps must be made using calibrated, ratcheting torque tools. Simple hand pliers do not exert the consistent pressure needed to form a gas-tight mechanical bond, leading to loose, high-resistance connections over time
- **Environmental Isolation:** Heat-shrinkable sleeves should be applied over exposed terminal barrels to insulate connections, reinforce strain relief, and protect conductors from environmental corrosion.
- **High-Frequency Noise Suppression (EMI mitigation):** Ferrite cores should be installed around sensitive signal and data lines located near high-noise components like VFDs to suppress high-frequency common-mode electromagnetic interference.
- **Choose the suitable type of connectors** for intended use of the cable

## Cable Manufactures

- [www.elettrotekkabel.com/](http://www.elettrotekkabel.com/)
- [lappusa.lappgroup.com](http://lappusa.lappgroup.com)
- [www.alphawire.com](http://www.alphawire.com)
- [www.elandcables.com](http://www.elandcables.com)
- [www.igus.pt/](http://www.igus.pt/)
- [www.clevelandcable.com/](http://www.clevelandcable.com/)
- [General cable](#)

## Standards and Approvals for electrical cables

### ■ United States - Key Standards & Regulations

- National Electrical Code® ([NFPA 70](#)) ([www.nfpa.org](http://www.nfpa.org))
- UL, Underwriters Laboratories, ([www.ul.com](http://www.ul.com))
  - UL83, UL 1277, UL 62, UL1581;
  - Markings: “UL Listed” or “UL Recognized”

### ■ Europe - Key Standards & Directives

- IEC, International Electrotechnical Commission ([www.iec.ch](http://www.iec.ch))
  - [IEC 60228:2023](#) - Conductors of insulated cables
  - [IEC 60287:2025 SER](#) - Electric Cables - all parts
  - [IEC 60364-5-52 60364-5-52:2009/AMD2024](#) - Low-voltage electrical installations - Part 5-52: Selection and erection of electrical equipment - Wiring systems
  - [IEC 60332:2025](#) - Tests on electric and optical fibre cables under fire conditions
  - [IEC 60502:2025 SER](#) - Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV)

## Standards and Approvals for electrical cables

### ■ Europe - Key Standards & Directives

- CPR: ([Construction Products Regulation - EN 50575](#))
- HAR, Harmonization Standard (set out by the European [CENELEC](#) , Marking: HAR symbol
- [CENELEC HD 603 S1](#) - Distribution Cables of Rated Voltage 0.6/1 kV
- UK, British Standard, (ex. BS EN 60228 Conductors of Insulated Cables)
- DE, VDE, Verband der Elektrotechnik ,Elektronik Informations technik e.V. (Association for Electrical, Electronic & Information Technologies) ([www.vde.com](http://www.vde.com))
  - VDE 0295, VDE 0281, VDE 0282

### ■ Approvals entities

- (USA) UL, Underwriters Laboratories, UL certifications
- (UK) BASEC: the British Approvals Service for Cables is an independent testing and approvals body for cable and wire ([basec.org.uk](http://basec.org.uk))