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Technical Note

Calculating the Current-Carrying Capacity of Cables in Single-Phase Cable System

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0 Overview

According to the IEC 60364-5-523: 1999 standard for copper core cables, this guide discusses how to calculate the current-carrying capacity of AC cables in the Single-Phase Cable System. It helps you select the right AC cables by considering rated current, ambient temperature, and installation method.

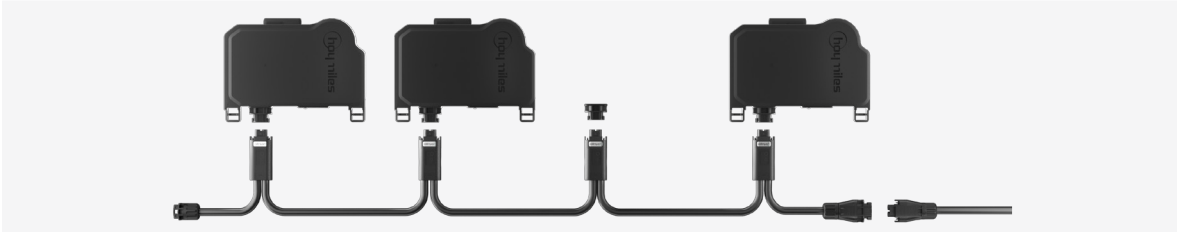


Figure 1- Flex-S2 Cable System

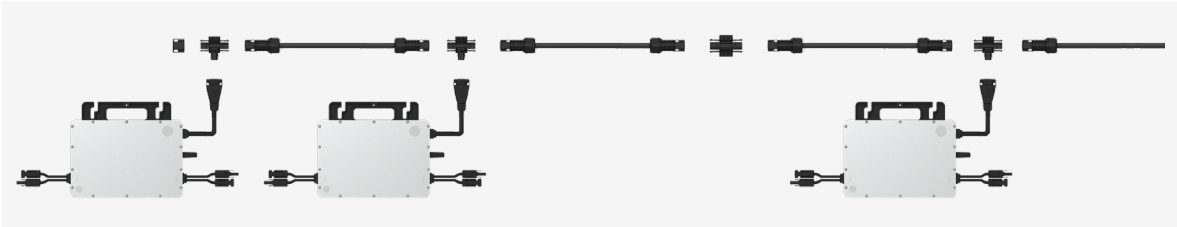


Figure 2- lex-S3 Cable System

1 Terms

- **Current-Carrying Capacity:** The maximum current a cable can carry safely and continuously under standard conditions without exceeding its long-term operating temperature.
- **Steady-State Temperature:** The temperature a cable reaches when heat dissipation and generation are balanced. At this point, the cable's temperature remains constant with no significant changes, as specified by the IEC standard.
- **Long-Term Operating Temperature:** The maximum temperature at which a cable can operate safely over a long period, depending on the insulation material's thermal resistance. Because the current flow generates heat that increases with the current, it's important to reduce the current flow to protect the cable's insulation from high temperatures.

2 Factors Affecting Current-Carrying Capacity

The current-carrying capacity of cables is primarily influenced by the conductor material, conductor size, number of conductors, type of insulation, ambient temperature, and installation method.

2.1 Conductor Material

Under standard test conditions, cables with higher conductivity materials generate less heat and have a higher current-carrying capacity. Copper and aluminum are the most common conductors. Copper has a higher electrical conductivity than aluminum, generating less heat for the same current and handling higher loads more efficiently. So microinverter systems typically use copper conductor cables.

2.2 Conductor Size

For the same type, the bigger the cable size, the larger the current-carrying capacity. The cross-sectional area of conductors is usually measured in mm^2. And the commonly used conductor sizes include 1.5 mm^2, 2.5 mm^2, 4 mm^2, and 6 mm^2.

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2.3 Number of Conductors

More conductors in a cable generate more heat, which reduces the cable's current-carrying capacity. In single-phase systems, the ground wire (PE wire) does not carry current and is not counted as a loaded conductor. So three-core cables and two-core cables have the same current-carrying capacity in single-phase cable systems.

2.4 Type of Insulation

The insulation type and its temperature limit affect the current-carrying capacity. Higher temperature limits allow for higher current capacity. Common insulation types and their temperature limits are:

Type of Insulation	Temperature Limit
Polyvinyl chloride (PVC)	70°C conductor
Cross-linked polyethylene (XLPE) and ethylene propylene compound (EPR)	90°C conductor

Table 1-Different Insulation Types and Corresponding Temperature Limits

The microinverter system generally uses the XLPE or EPR cable.

2.5 Ambient Temperature

The current-carrying capacity increases when the ambient temperature is below the standard temperature and decreases when it is above. The ***IEC 60364-5-523: 1999*** standard specifies the following standard temperatures for copper cables:

- **In the Air:** 30°C is the standard ambient temperature, regardless of installation method.
- **In the Ground:** 20°C is the standard ambient temperature, whether directly buried or in underground conduits.

2.6 Cable Laying Method

2.6.1 Installation Method

The installation method you choose affects a cable's heat dissipation and current-carrying capacity. Here are some common methods:

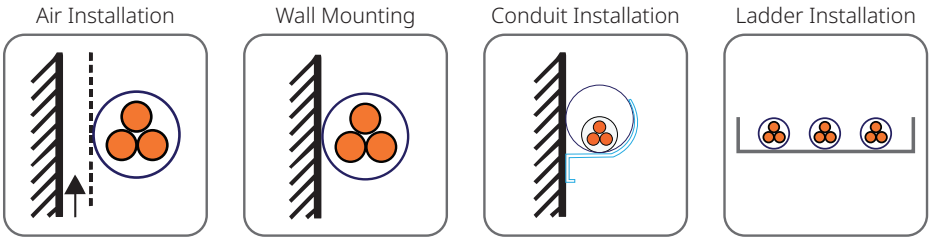


Figure 3-Installation Methods

In microinverter systems, AC cables are typically fixed to the mounting rail and installed in the air or mounted on walls.

- **Air Installation:** Cables are considered air-installed if they are spaced no less than 0.3 times the cable's outer diameter from any surface.
- **Wall Mounting:** If cables droop and touch the roof surface, they are considered wall-mounted to ensure system safety and reliability.



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2.6.2 Cable Arrangement and Cable Spacing

The arrangement and spacing of cables affect their current-carrying capacity. Cables installed together have a lower capacity than a single cable. Cables that touch each other in the air have a lower capacity than those that are spaced apart.

Cable spacing is classified as follows (where 'a' represents the spacing between cables, and 'De' represents the cable's diameter):

- **Touching:** If cables are spaced less than one cable's outer diameter apart, heat dissipation will be restricted. Apply a correction factor when calculating the current-carrying capacity.
- **Spaced Installation 1:** If cables are spaced between one and two times their outer diameter apart, a correction factor is needed when calculating the current-carrying capacity.
- **Spaced Installation 2:** If cables are spaced more than two times their outer diameter apart, no correction factor is required.

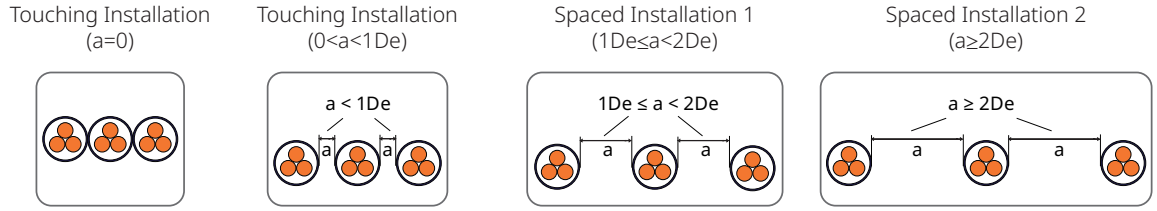


Figure 4-Installation Method

Proper planning of cable layout and spacing optimizes heat dissipation and enhances current-carrying capacity. If sufficient spacing cannot be maintained, calculate correction factors to account for the impact on current capacity.

3 Method for Calculating Current-Carrying Capacity

Hoymiles follows the *IEC 60364-5-523: 1999* standard to calculate the base current capacity for copper cables. For cables installed against walls in normal conditions, the base current capacity is:

Standard Ambient Temperature	Installation Method	Number of Loaded Conductors	Insulation Type
30 °C	wall-mounted	two-core, loaded	XLPE, EPR

Cable Size	Current-Carrying Capacity
2.5 mm²	33 A
4 mm²	45 A
6 mm²	58 A

Table 2-Recommended Current-Carrying Capacities at Standard Temperature

Hoymiles recommends using these base current ratings as a reference, but you should adjust the actual current-carrying capacity of AC cables based on environmental conditions and installation methods.

3.1 Influencing Factors

3.1.1 Ambient Temperature

Ambient temperature is a key factor that affects a cable's current-carrying capacity. The higher the temperature, the lower the current-carrying capacity.

During installation, you need to adjust the base current ratings according to the actual temperature on site.

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The *IEC 60364-5-523: 1999* standard provides correction factors for different temperatures.

Ambient Temperature (°C)	Correction Factor (XLPE/EPR)
10	1.15
15	1.12
20	1.08
25	1.04
30	1
35	0.96
40	0.91
45	0.87
50	0.82
55	0.76
60	0.71

Table 3-Temperature Correction Factors

Note: Calculating the Current-Carrying Capacity of the V-Cable, W-Cable, and Flex-S3 Connection Cable:

Step 1: Determine the temperature correction factor. *Considering the extreme high temperature, Hoymiles uses 55°C as the ambient temperature for calculating the current-carrying capacity. According to Table 3-Temperature Correction Factors, the correction factor for 55°C is 0.76. (If the cable is freely installed in the air, the maximum temperature is the highest daily temperature of the hottest month; if the cable is in a conduit, it is the average monthly temperature of the hottest month.)*

Step 2: Calculate the current-carrying capacity at 55°C. *Using data from Table 2-Recommended Current-Carrying Capacities at Standard Temperature, the current-carrying capacities for three different cable sizes are:*

$2.5\ mm^2$: $33\ A \times 0.76 \approx 25\ A$

$4\ mm^2$: $45\ A \times 0.76 \approx 34\ A$

$6\ mm^2$: $58\ A \times 0.76 \approx 44\ A$

Step 3: Adjust based on the maximum current supported by the cable connectors. *The connectors in the AC Trunk support a maximum current of 40 A. For long-term, safe, and reliable operation at 55°C, the recommended current-carrying capacities are 25 A, 34 A, and 40 A respectively.*

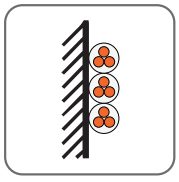
3.1.2 Installation Method

Different installation methods affect heat dissipation and thus the current-carrying capacity. Common installation methods include mounting on walls, using conduits, or laying them in cable trays. (There are three types of cable trays: ladder trays, solid trays, and perforated trays.) You should consider the correction factor for the installation method in your calculations.

Method 1: Outdoor Use Cable, Single Layer On The Wall

Ensure a clearance of at least twice the cable outer diameter between adjacent cables.

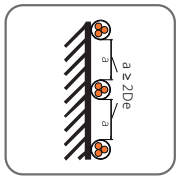
Touching Installation



Spaced Installation 1



Spaced Installation 2



Number of Cables	Cable Laying Spacing (a represents the spacing between cables, and De is the cable's outer diameter)		
	Touching Installation Correction Factor (0 < a < 1De)	Spaced Installation Correction Factor 1 (1De ≤ a < 2De)	Spaced Installation Correction Factor 2 (a ≥ 2De)
1	1	/	1

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2	0.85	/	1
3	0.79	/	1
4	0.75	/	1
5	0.73	/	1

Table 4-Correction Factors for Cables Installed on a Wall

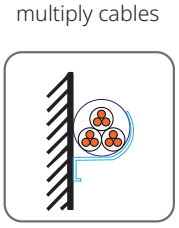
Note: For scenarios not explicitly covered by regulations, a "/" is used in the correction factor table. In these cases, choose a lower (more conservative) correction factor for your calculations. For instance, if the spacing between two cables is 1.5 times the cable's diameter, use the correction factor for closely spaced cables.

Method 2: In a Conduit

If local regulations prohibit exposed outdoor cables, use conduit or track-laying methods. For conduit laying, try to run each cable individually through a conduit to minimize mutual interference.

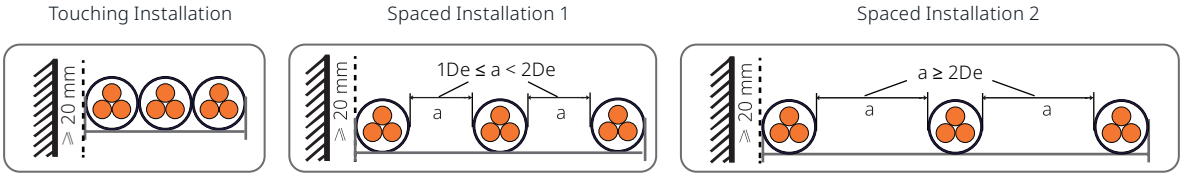
Number of Cables	Correction Factor
1	1
2	0.8
3	0.7
4	0.65
5	0.6

Table 5-Correction Factors for Cables Installed In a Conduit



Method 3: On a Ladder Tray

For ladder trays, we recommended to use a spaced installation whenever possible. If cables are installed touching on the ladder tray, apply the appropriate correction factors.



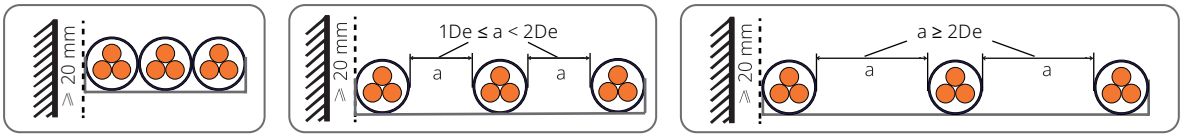
Number of Cables	Cable Laying Spacing (a represents the spacing between cables, and De is the cable's outer diameter)		
	Touching Installation Correction Factor (0 < a < 1De)	Spaced Installation Correction Factor 1 (1De ≤ a < 2De)	Spaced Installation Correction Factor 2 (a ≥ 2De)
1	1	1	1
2	0.87	1	1
3	0.82	1	1
4	0.8	1	1
6	0.79	1	1

Table 6-Correction Factors for Cables Installed on a Ladder

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Method 4: Unperforated Cable Tray

Touching Installation | Spaced Installation 1 | Spaced Installation 2

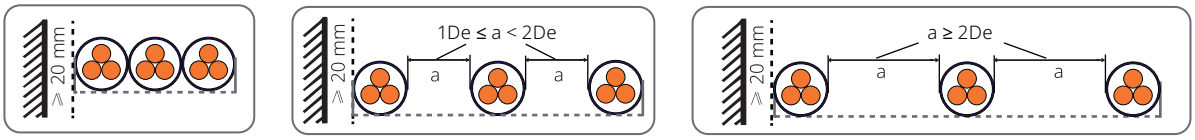


Number of Cables	Cable Laying Spacing (a represents the spacing between cables, and De is the cable's outer diameter)		
	Touching Installation Correction Factor (0 < a < 1De)	Spaced Installation Correction Factor 1 (1De ≤ a < 2De)	Spaced Installation Correction Factor 2 (a ≥ 2De)
1	1	/	1
2	0.85	/	1
3	0.79	/	1
4	0.75	/	1
6	0.72	/	1

Table 7-Correction Factors for Cables Installed on an Unperforated Cable Tray

Method 5: Perforated Cable Tray

Touching Installation | Spaced Installation 1 | Spaced Installation 2



Number of Cables	Cable Laying Spacing (a represents the spacing between cables, and De is the cable's outer diameter)		
	Touching Installation Correction Factor (0 < a < 1De)	Spaced Installation Correction Factor 1 (1De ≤ a < 2De)	Spaced Installation Correction Factor 2 (a ≥ 2De)
1	1	1	1
2	0.88	1	1
3	0.82	0.98	1
4	0.79	0.95	1
6	0.76	0.91	1

Table 8-Correction Factors for Cables Installed on a Perforated Cable Tray

3.2 Calculation Steps

Find the base current-carrying capacity from IEC 60364-5-523: 1999 based on cable specs and installation methods.

Adjust for ambient temperature using the temperature correction factor.

Apply the laying method correction factor based on arrangement and spacing.

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3.3 Examples

3.3.1 Example 1

Project Details				
Highest Ambient Temperature	Installation Method	Number of Cables	Cable Size	Cable Type
45°C	Wall Mounting	3	6 mm²	Copper core

- Calculate rated current-carrying capacity at the standard ambient temperature.
- Calculate current-carrying capacity at the actual ambient temperature.
- Determine installation method and adjust current-carrying capacity.

The rated current-carrying capacity for a 6 mm² copper core cable wall mounted at 30°C is 58 A (see *Table 2-Recommended Current-Carrying Capacities at Standard Temperature*).

At 45°C, the correction factor is 0.87. (see *Table 3-Temperature Correction Factors*) . So the current-carrying capacity is 50.46 A (58 A × 0.87).

The correction factor is 0.79 when three cables are touching and mounted on a wall. If the three cables are spaced apart (spaced installation 1), the factor is 1. If they are spaced even further (spaced installation 2), the factor is 1 (see *Table 4-Correction Factors for Cables Installed on a Wall*).

- touching: 39.86 A (50.46A × 0.79);
- spaced installation 1: 50.46 A (50.46A × 1) ;
- spaced installation 2: 50.46 A (50.46 A × 1).

3.3.2 Example 2

Project Details				
Highest Ambient Temperature	Installation Method	Number of Cables	Cable Size	Cable Type
40°C	Ladder Installation	6	4 mm²	Copper core

- Calculate rated current-carrying capacity at the standard ambient temperature.
- Calculate current-carrying capacity at the actual ambient temperature.
- Determine installation method and adjust current-carrying capacity.

The rated current-carrying capacity for a 4 mm² copper core cable wall mounted at 30°C is 45 A (see *Table 2-Recommended Current-Carrying Capacities at Standard Temperature*).

At 40°C, the correction factor is 0.91. (see *Table 3-Temperature Correction Factors*) . So the current-carrying capacity is 40.95 A (45 A × 0.91).

The correction factor is 0.79 when six cables are touching a ladder. If the six cables are spaced apart (spaced installation 1), the factor is 1. If they are spaced even further (spaced installation 2), the factor is 1 (see *Table 6 -Correction Factors for Cables Installed on a Ladder*).

- touching: 32.35 A (40.95 A × 0.79);
- spaced installation 1: 40.95 A (40.95A × 1);
- spaced installation 2: 40.95 A (40.95A × 1).

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