NEC Compliance For Cable Bus Systems

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In this article we will explore how the **NEC Rule 110.14C** affects the ampacity calculations and cable bus sizing through a detailed example. The Power Bus Way Ltd cable bus system complies with the **NEC Article 370**, and it is fully certified/tested to the **ANSI/CSA C22.2 No. 273:19** Standard. In order to gain a comprehensive understanding, let's begin by addressing the following question:

Can you terminate free-air rated cable bus onto Low Voltage (LV) equipment in the USA?

The NEC Article 100 defines "free air" as an "Open or ventilated environment that allows for heat dissipation and air flow around an installed conductor.". The cable bus, being a ventilated metal enclosure, can comply with the NEC definition of free air. Does this mean that cable bus can use **NEC Table 310.17** to size the cable bus system and terminate onto a LV equipment? Before we go ahead and turn the page on this, we need to explore the limitations that are present for LV equipment termination.

Free-air rated cable bus (see **NEC Article 370** for cable bus guidelines) systems can be terminated onto Low Voltage (LV) equipment in the US, but by doing so, you may not be NEC compliant. To better understand this, we need to look at the codes and constraints that the cable bus faces from source equipment to load equipment. Let's look at the codes and constraints that the cable bus faces with an example.

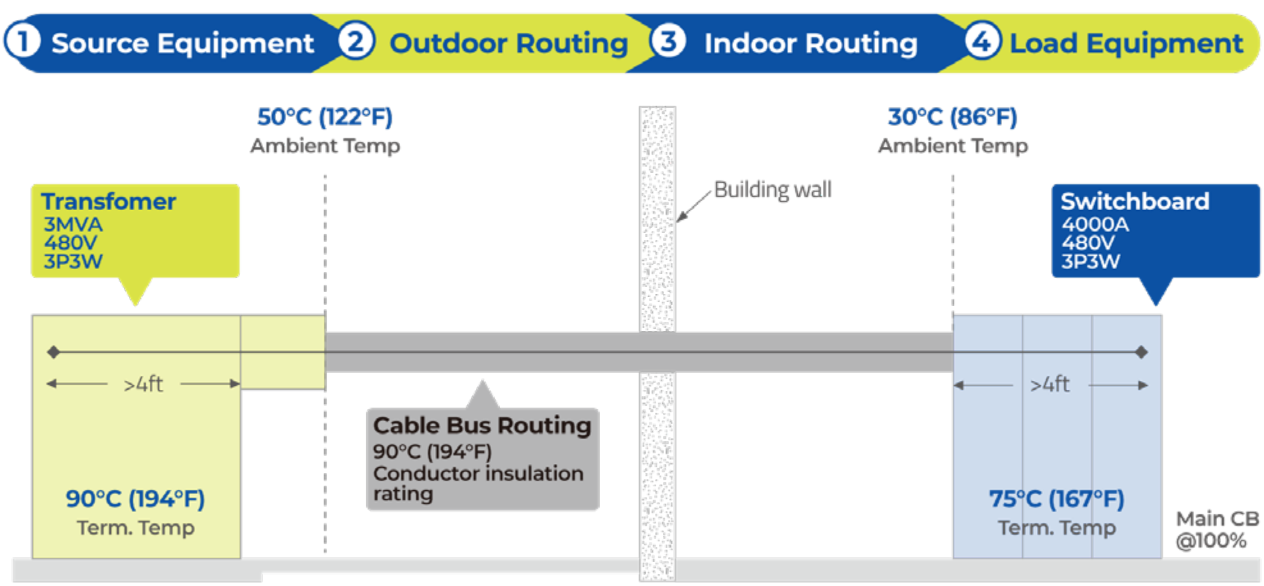

Figure 1. Cable bus sizing breakdown per section

See figure 1, for a typical cable bus installation. This example shows a cable bus connecting the secondary of a transformer to the switchboard inside the electrical room. This will show the equipment temperature rating for both equipment as well as the ambient temperatures that the cable bus system will be subjected to.

Let us break this example in (4) four sections (see figure 1):

1 Source equipment	The ampacity requirement coming out of the source equipment.
2 Outdoor cable bus routing	What the ambient temperature correction factor is required for the outdoor portion of the cable bus routing.
3 Indoor cable bus routing	This section deals with the ambient temperature correction factor requirement throughout the indoor cable bus routing portion before terminating at the load equipment.
4 Load equipment	The ampacity rating that the cable bus is subjected to, based on the equipment's temperature rating, and the **NEC Rule 110.14(C).**

In this example we will be referencing the NEC Table 310.16 (non-free air ampacities) and NEC Table 310.17 (free air ampacities). The use of these tables is dictated by the temperature ratings of the equipment being connected to.

Section #1 Source Equipment

In this example we have a 3MVA transformer as our source equipment. Using the details provided in the example in Figure 1, we get the following information:

VA Transformer Rating	$Vsec$ Secondary Voltage	° Transformer Temperature Rating
3MVA	480V	90°C (194°F)

$$I_{sec} = \frac{3MVA}{480V_{sec} * \sqrt{3}} = 3{,}613A$$

The formula above uses the volt-amp rating of the transformer, the secondary voltage, and root (3) for its 3-phase component, which yields the ampacity output from the secondary. This will be the minimum ampacity our cable bus system will need to be sized to at the source equipment.

Assuming we are using 500kcmil copper (CU) XHHW-2 LV power cables for this connection, then we get the following allowable ampacity using **NEC Table 310.17**:

For 500MCM CU LV @90°C (194°F) operating temperature with
30°C (86°F) ambient temperature we get 700A.

This is due to transformers normally rated at 90°C (194°F).

Now we can do the following operation:

$$Cables\ Per\ Phase = \frac{3613A}{700A} = 5.16 \rightarrow 6$$

The source equipment in this example has a requirement of at least 6 cables per phase.

Section #2

Outdoor Cable Bus Routing

For this section, we will not consider any equipment for our calculations. The only modifier to the cable bus ampacity at this stage will be the highest ambient temperature present along the outdoor routing of the cable bus system.

The LV power cables that Power Bus Way Ltd (PBW) uses in LV cable bus requests are all rated at 90°C (194°F).

The NEC Table 310.16 and NEC Table 310.17 are both at 30°C (86°F) ambient and will require a temperature correction factor should the ambient temperature be higher than 30°C (86°F) as shown in the NEC Rule 310.15. The ambient temperature present in the outdoor cable bus routing shown in Figure 1, is of 50°C (122°F). We can get the correction factor needed for 50°C (122°F) using the NEC Table 310.15(B)(1), or use the equation shown in NEC 310.15(B). We will use the equation to show you the most appropriate way.

The equation found in NEC 310.15(B) goes as follows:

$$I' = I\sqrt{\frac{(T_c - T'_a)}{(T_c - T_a)}}$$

I' Ampacity corrected for 50°C (122°F) ambient temperature

I Allowable ampacity based on the insulation found on NEC Table 310.17 @90°C (194°F)

T_c Temperature rating of the conductor (°C)

T'_a New ambient temperature (°C)

T_a Ambient temperature used in the table (°C)

Now we put the values we know in the equation.

$$I' = 700A\sqrt{\frac{(90-50)}{(90-30)}} = 571.5476A \rightarrow 571.5A$$

Now that we have the ambient corrected allowable ampacity, we can get the true number of cables per phase needed. To achieve this, we will perform the following operation:

$$\#\ of\ Cables\ Per\ Phase = \frac{system\ ampacity}{conductor\ allowable\ ampacity}$$

When we input the values, we get the following:

$$\#\ of\ Cables\ Per\ Phase = \frac{4000A}{517.5A} = 6.9991 \rightarrow 7\ cables\ per\ phase$$

This results in the cable bus system along the outdoor routing has a requirement of at least 7 cables per phase.

Section #3

Indoor Cable Bus Routing

(Ex.: Electrical Room)

As we extend past the wall penetration into the building, the cable bus will experience a different ambient temperature than the outdoor portion. This section only considers the ambient temperature after entering the building and into the electrical room itself. The ambient temperature specified in Figure 1, is of 30°C (86°F) which is the same as the ambient temperature in both the NEC Table 310.16 and NEC Table 310.17. This means that there is no need for any ambient correction.

This allows us to go ahead and perform the following operation based on the NEC Table 310.17 without applying a temperature correction factor:

$$\#\ of\ Cables\ Per\ Phase = \frac{system\ ampacity}{conductor\ allowable\ ampacity}$$

When we input the values, we get the following:

$$\#\ of\ Cables\ Per\ Phase = \frac{4000A}{700A} = 5.714 \rightarrow 6\ cables\ per\ phase$$

This results in the indoor cable bus system having a requirement of at least 6 cables per phase.

Section #4

Load Equipment

This section will focus on the ampacity rating at the switchboard shown in Figure 1, and any codes and rules that apply. Here are some details to note:

LV switchgears are typically rated at 75°C (167°F) unless specified and marked otherwise.
Cable bus is terminating at a 4000A 100% rated circuit breaker.
LV equipment terminations are governed by the **NEC Rule 110.14(C)**.

To be able to understand this sections we need to dive into the NEC Rule 110.14(C).

What is NEC Rule 110.14(C)?

NEC Rule 110.14(C) is a provision within the NEC that addresses the temperature rating associated with the conductor ampacity and its relationship to the equipment termination's temperature rating. This rule ensures that the selected ampacity for a conductor does not exceed the lowest temperature rating for any connected termination, conductor, or device. This leads to the main limitation for ampacity selection, and that is the statement made in the NEC Rule 110.14(C)(1). It states that unless the equipment is listed and marked otherwise, conductor ampacities used for determining equipment termination provisions should be based on NEC Table 310.16.

If the use of NEC Table 310.17 in sections 1, 2, and 3 is acceptable, then why does the NEC Rule 110.14(C) exist and limits the cables bus terminating at the load equipment? The reason for this is that most LV UL product standards use the 75°C (167°F) column of NEC Table 310.16 for testing their equipment. This pushes the standard to limit the feeder sizing to what the load equipment has been tested to, and not to what the power feeder can handle. When the load equipment manufacturers test their products using cables rated with the NEC Table 310.17, then we will say a change in the code that will allow the use of free air rated cables in section 4 of the example.

Applying this rule will look like this:

Using the NEC Table 310.16 to get the allowable ampacity of a 500MCM CU LV @75°C (167°F) operating temperature with 30°C (86°F) ambient temperature we get **380A**.

$$\# \textit{ of Cables Per Phase} = \frac{\textit{system ampacity}}{\textit{conductor allowable ampacity}}$$

When we input the values, we get the following:

$$\# \textit{ of Cables Per Phase} = \frac{4000A}{380A} = 10.52 \rightarrow 11 \textit{ cables per phase}$$

This results in the cable bus system within the electrical room has a requirement of at least 11 cables per phase.

The allowable ampacities and parallel runs required per section

	Section 1 Source Equipment	Section 2 Outdoor Cable Bus Routing	Section 3 Indoor Cable Bus Routing	Section 4 Load Equipment
Ampacity Rating	3613A	4000A	4000A	4000A
Allowable Ampacity	700A	571.5A	700A	380A
Cables Per Phase	6	7	6	11
Applicable Tables	Table 310.17	Table 310.17 Equation 310.15 Table 310.15(B)(1)	Table 310.17	Table 310.16 (Due to Rule110.14(C) & Rule 310.15(A))

To properly size the cable bus enclosure, we need to not only consider the cable bus ability to use free air ampacity, but also the limitations of the equipment to which we are connecting. There are ampacity limitations such as overcurrent protection devices that we terminate to, but also the equipment temperature restrictions. Therefore, to ensure compliance with the NEC requirements for conductor sizing and equipment termination, you should use the ampacity values provided in NEC Table 310.16 unless specified otherwise by the engineer.

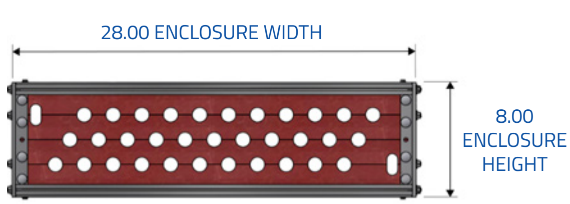

Figure 2. The cross-sectional design of the resulting cable bus system driven by Section 4