

TechTopics No. 90

Temperature ratings for external cables

One of the issues that is addressed in the standards for switchgear and controllers is that of coordination of the temperatures in switchgear or controller equipment with those of the user's power cables used for incoming and outgoing power connections. The temperatures obtained in the switchgear or controller must not cause heating in cables that stress them beyond their ratings, nor can the cables cause heating problems in the switchgear or controller.

The temperature limitations in switchgear assemblies and medium-voltage controllers are based on the use of cables with insulation rated for 90 °C. The actual language of the standards varies according to the type of equipment, but the intent is essentially the same.

Metal-clad switchgear and metal-enclosed interrupter switchgear

For switchgear assemblies constructed to IEEE Std C37.20.2 (metal-clad switchgear) and IEEE Std C37.20.3 (metal-enclosed interrupter switchgear), the allowable temperature rise at the terminals to which user's cables are connected is 45 °C over a 40 °C ambient outside the enclosure (reference, IEEE Std C37.20.2 table 3, for connections that are silver- or tin-surfaced). The table adds a footnote that these temperature limits are based on 90 °C insulated cable. Clause 5.5.5 of the standard elaborates and says

“This temperature limitation is based on the use of 90 °C insulated power cables. Use of lower temperature rated cables requires special consideration.”

For metal-enclosed interrupter switchgear (IEEE Std C37.20.3), the language differs editorially, but the functional requirement is the same as for metal-clad switchgear.

Low-voltage metal-enclosed switchgear

The standard for this equipment is IEEE Std C37.20.1. The requirements are equivalent to those in C37.20.2 and C37.20.3. However, as will be discussed, National Electric Code® (NEC®) treats them differently.

Medium-voltage controllers

For medium-voltage controllers, the applicable standard is UL 347 (fifth edition), which has replaced the historic ICS-2 standard for motor controllers. Table 2 of this standard allows a temperature rise of 50 °C at the terminals to which the user's cables are connected, and a total temperature of 90 °C when the exterior ambient upper limit of 40 °C is considered. As with switchgear assemblies, this is predicated on the use of insulated power cables rated for 90 °C use. The UL standard adds a bit more explanation as “The temperature on a wiring terminal or lug is measured at the point most likely to be contacted by the insulation of a conductor installed as in actual service.”

From this, it is very clear that the requirements of the switchgear assemblies standards and the medium-voltage controllers standard are synchronized with the use of 90 °C insulated power cables.

National Electrical Code (NEC®) considerations

The NEC considers the temperature rating of terminals for connection to external cables somewhat differently. For low-voltage equipment, NEC 110.14(C)(1)(b)(2) indicates that conductors with temperature ratings higher than 75 °C can be used, but ampacity must be in accordance with the 75 °C ampacities shown in table 310.15(B)(16). Since switchgear in accordance with IEEE C37.20.1 is tested based on the use of 90 °C insulated power cables, the user should be able to take advantage of the higher ampacity of the 90 °C cables as compared to 75 °C ampacities. However, the user is encouraged to seek agreement to this from the Authority Having Jurisdiction (AHJ), as some inspection authorities insist on 75 °C ampacities.

For medium-voltage, the NEC is somewhat more certain. NEC 110.40 says that the user's power cables shall be permitted to use the 90 °C temperature rating and ampacity as given in tables 310.60(C)(67) through 310.60(C)(86), as applicable to the particular cable.

Excerpts from the NEC articles 110.14 and 110.40 at provided at the end of this issue of TechTopics.

Higher cable temperature ratings – 105 °C

It is recognized that some newer cable types are rated for 105 °C insulation temperature. Such cables should be used at their 105 °C ampacities only with considerable caution. If a circuit has a full-load capability that is lower than the rating of the switchgear feeder circuit breaker that serves the feeder, then the temperature rise of the switchgear will be lower than the standard limit, and additional heat given off by the cables will likely not be deleterious.

For example, if a circuit breaker feeder rated 1,200 A is feeding a cable circuit with a full load requirement of 900 A (75 percent), then the temperature rise of the cable terminal mounting pad, normally 45 °C, is reduced to about 25 °C ($0.75 \times 0.75 \times 45 = 25$ °C). In this situation, the additional heat of "hot" cables would not be an issue.

However, consider the same 1,200 A feeder, supplying a cable circuit with a full-load current of 1,200 A. In this case, the cable terminal mounting pad should be considered to be at 45 °C temperature rise, but the cable would not be at 90 °C – instead, the cable would be at 105 °C. In this condition, heat would be conveyed into the switchgear from the "hot" cables, and the performance (and life expectancy) of the switchgear could be adversely affected.

Lower cable temperature ratings – 75 °C

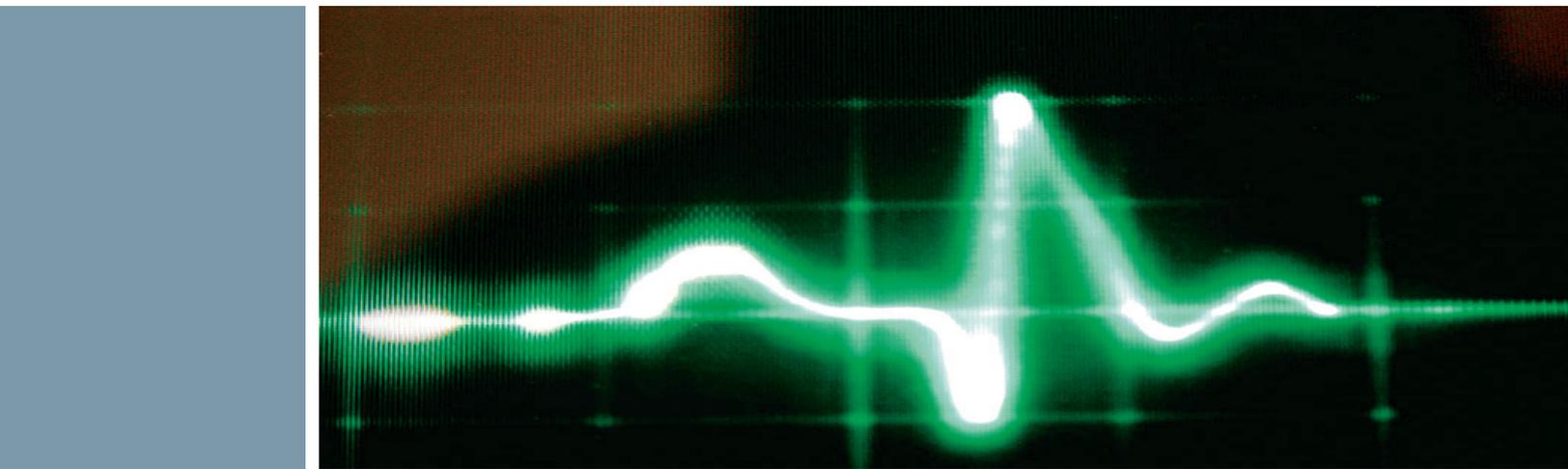
A reverse situation applies if the user's cables have a rated temperature of 75 °C. In this situation, if the circuit is loaded to the full continuous current rating of the switchgear feeder circuit breaker unit, the terminations in the switchgear will be at 45 °C temperature rise, and total temperature suitable for 90 °C cables but too hot for 75 °C cable insulation. The temperature rise of the cable terminal mounting pad for the external cable terminal lugs would need to be reduced so that the temperature rating of the cable insulation (75 °C) is not exceeded. As discussed in the preceding section, this is a situation in which loading at a fraction of the switchgear rating is very helpful. In the 900 A load/1,200 A circuit breaker example, the temperature rise of the terminal pads is reduced from 45 °C to about 25 °C, and this 20 °C reduction brings the temperature of the cable terminal mounting pad down to the temperature rating (75 °C) of the cable insulation.

It appears that few, if any, power cable manufacturers still offer 75 °C rated cables, so this situation is not very typical of modern installations.

Summary

All of this discussion has considered only the temperatures in the switchgear and the temperatures of the cables and the cable insulation. However, there is another factor that is involved in any real situation, and that is the consideration of voltage drop in the system. While higher temperature ratings on cables allow for heavier loading on cables, they result in greater voltage drop in the conductors. Voltage drop and power quality issues are assuming greater importance, and this often results in the need to increase the size of cables to reduce voltage drop.

In sum, medium-voltage switchgear assemblies and medium-voltage controllers are designed and tested for use with power cables having a 90 °C temperature rating. The user is encouraged to consult with the local AHJ to determine if the ampacities of 90 °C cable can be utilized. Care should be exercised if the user intends to use class 105 °C cables at the 105 °C ampacities.



Excerpts from NEC:

“110.14 Electrical Connections...

(1) Equipment Provisions. The determination of termination provisions of equipment shall be based on 110.14(C)(1)(a) or (C)(1)(b). Unless the equipment is listed and marked otherwise, conductor ampacities used in determining equipment termination provisions shall be based on Table 310.15(B)(16) as appropriately modified by 310.15(B)(6).

...

110.14(C)(1)

(b) Termination provisions of equipment for circuits rated over 100 amperes, or marked for conductors larger than 1 AWG, shall be used only for one of the following:

(1) Conductors rated 75 °C (167 °F)

(2) Conductors with higher temperature ratings, provided the ampacity of such conductors does not exceed the 75 °C (167 °F) ampacity of the conductor size used, or up to their ampacity if the equipment is listed and identified for use with such conductors

110.40 Temperature Limitations at Terminations. Conductors shall be permitted to be terminated based on the 90 °C (194 °F) temperature rating and ampacity as given in Table 310.60(C)(67) through Table 310.60(C)(86), unless otherwise identified.”

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