

# TechTopics No. 86

## Use of unshielded cables for connections in medium-voltage switchgear and motor controllers

Several years ago, the National Electrical Code (NFPA 70® or NEC®) was revised to require that insulated cables for feeder circuits over 2,000 volts phase-to-ground use shielded cable construction. For decades, the code had allowed use of unshielded cables for feeder circuits. This change in the code has caused users to ask why it is that switchgear manufacturers still continue to use unshielded cables inside of the switchgear.

Article 300 of the NEC covers wiring methods. Article 300.1(B) indicates that the provisions of article 300 do not apply to conductors that are an integral part of equipment, including “factory assembled control equipment” and “listed utilization equipment”. The code actually says:

**(B) Integral parts of equipment.**

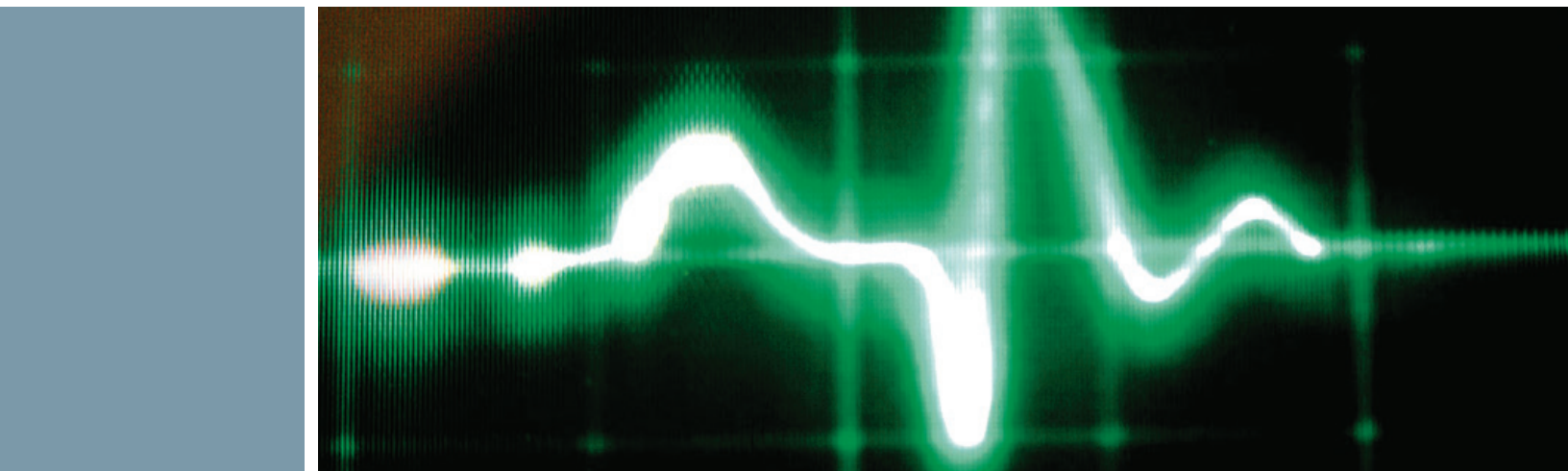
The provisions of this article are not intended to apply to the conductors that form an integral part of equipment, such as motors, controllers, motor control centers, or factory assembled control equipment or listed utilization equipment.

This statement in the code has been unchanged since at least the 1993 edition (if not earlier) of the NEC.

Article 300.1(B) provides the clear basis for use of unshielded cables inside medium-voltage switchgear and medium-voltage motor controllers. The procedures and standards that third-party certification agencies (including Underwriters Laboratories (UL), Canadian Standards Association (CSA), and others) use to investigate compliance of switchgear and motor controller designs to determine if a listing mark can be applied to the products include the NEC. In short, for a product to be UL-Listed or C-UL Listed, it must meet the NEC.

As used in factory-assembled products, the unshielded cable is mounted on insulating supports, particularly when the rated voltage of the product exceeds the rating of the cable itself. For example, 15 kV cable is used for connections to voltage transformers, control power transformers, and surge arresters in metal-clad switchgear rated up to 38 kV. The requirement of the standards is that the assembled equipment be able to withstand dielectric tests, including lightning impulse withstand tests and power frequency withstand tests at the ratings of the equipment (in the case of 38 kV metal-clad switchgear, 150 kV BIL and 80 kV one-minute 60 Hz withstand voltage). The equipment is able to meet these requirements because the total insulation system, including the air surrounding the cables, the dielectric strength of the insulating supports, and the dielectric strength of the cable insulation, is sufficient to pass the tests for the complete switchgear.

Shielding of cables in feeder circuits outside of the factory-assembled switchgear or controllers is required by the code. The shield is a grounded outer covering for the cable. The purpose of the shield is to confine the electric field between the conductor and the grounded shield so that the dielectric stress on the insulation is uniformly and symmetrically distributed around the circumference of the cable, and so that the installation is free of sharp concentrations of dielectric stress. The shield must be in intimate contact with the insulation.



For factory-assembled equipment, the high-voltage components are enclosed in an overall metal enclosure, so that a shield on individual conductors in the equipment is unnecessary. Further, in the equipment, the design of the cable support system avoids sharp concentration of dielectric stress so that a shielded cable is not needed.

Terminations of the shielded cable must also be made with care, to provide for a smooth dielectric transition from the shielded condition to the unshielded condition. This transition is usually done using a stress cone kit to terminate the shield and move the grounded exterior away from the conductor while reducing the unit dielectric stress. For decades, stress cones were created using a great deal of electrical tape and substantial labor, but the process has evolved greatly over the years with the advent of convenient stress cone termination kits from a number of manufacturers.

Another significant drawback to stress cones in switchgear and controllers is the substantial space required if shielded cables were used. Shielded cables require a significant amount of space at each end of the cable for installation of the stress cone kit. Also, the minimum bending radius for shielded cables is twelve times cable outside diameter, whereas the minimum bending radius for unshielded cables is only eight times outside diameter (and even less with extra-flexible appliance connection cables used in controllers).

The two factors, high cost and large space requirements, preclude use of shielded cable in switchgear.

For further discussion of the use of cables in medium voltage equipment for connections between components, please refer to TechTopics No. 60.

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