

# TechTopics No. 33

## Clearance requirements in switchgear and control equipment

A question that arises periodically concerns the requirements of the standards regarding clearance between conductors or between conductors and ground in switchgear and control equipment. The question usually refers to the nebulous term, “the standards”, suggesting confusion as to what “the standards” might be. A number of these issues of TechTopics have dealt with discussions of the various standards developing organizations, and the reader is referred to them for background discussion. For the purposes of this issue of TechTopics, “the standards” are:

- IEEE C37-series standards for high-voltage circuit breakers and switchgear assemblies, including C37.04, C37.09, C37.20.2, and C37.20.3.
- ANSI C37.54, C37.55, C37.57, and C37.58, conformance test standards supplementing the IEEE C37 standards.
- UL 347, for medium-voltage controllers (which replaces the older NEMA ICS3 standard).

Except for UL 347, these standards do not specify minimum clearances in switchgear or control equipment. UL 347 is an exception, as it does provide minimum clearances, but our experience indicates that if the minimum clearances used in UL 347 are actually used in a product, the product will not meet the dielectric test voltage levels in UL 347.

So, if “the standards” do not specify minimum clearances, what does the manufacturer use, and how does the user know that they receive a product that performs in accordance with the standards? The answer to this hinges on a basic philosophy of IEEE standards, as well as UL standards. The basic philosophy is that the manufacturer is free to design the equipment in whatever manner they desire, provided that the product must pass the design (type) tests in the respective standards.

In the case of equipment investigated by UL, these design tests are conducted with UL participation as part of the UL procedures for investigation of products.

The standards require that the manufacturer demonstrate the dielectric performance of the products to the conditions as given in the standards during design tests, which for clearance discussions are the one-minute power frequency withstand voltage test (high potential, or hipot) and the lightning impulse withstand voltage test, which demonstrates the basic insulation level or basic impulse level (BIL) of the equipment. For example, the hipot test voltage for 15 kV metal-clad switchgear is 36 kV for one minute, while the impulse test voltage for this equipment is 95 kV (with the standard 1.2 x 50  $\mu$ s wave shape).

The dielectric performance of the equipment is affected by a great many factors, including:

- Distance between conductors, and to the enclosure
- Shape of the conductors and adjacent conductive elements including those of the enclosure
- Insulation, if any, on the conductors
- Atmospheric conditions, including atmospheric pressure and humidity
- Cleanliness of the equipment
- Aging of insulation.

The shape of the conductors and the shape of nearby enclosure parts is critical. In typical switchgear or controller sections, the conductors may be oriented with flat surfaces towards each other, or with the narrow edges towards each other.

The nearby enclosure elements may be smooth (a steel panel) or may have protruding sharp edges (the flange of a formed panel or structural support). Conductors may run in parallel, or may cross each other at an angle. Conductor joints and their protruding hardware also affect the dielectric performance. The profile of the conductor is also very significant, and is in fact why bus bars in medium-voltage equipment are almost always full-round-edge bars. Square-edged bus bars must be used with care as the sharp corners require greater clearance to achieve the same dielectric performance. Sharp corners result in higher dielectric stress than that with rounded edges.

As if this were not sufficiently complicated, add the complication of insulated conductors and uninsulated conductors. Even in metal-clad switchgear, there are numerous elements of the equipment where conductive materials are not insulated, such as at primary disconnects, on voltage or control power transformers, at the vacuum interrupter of circuit breakers and other areas. Insulation is used to decrease the likelihood of dielectric failures as well as to allow for a reduction in the size of switchgear structures. In areas where the conductors are insulated, the space between conductors or to ground can be much lower than would be possible with uninsulated conductors.

The great variety of dielectric conditions inside the switchgear or controller leads to the conclusion that no single clearance distance between conductors, or between conductors and ground, gives assurance that the equipment will meet the dielectric performance required by the standards. The only valid way to have confidence in the design of the equipment is to subject it to the dielectric tests required by the standards.

Each manufacturer has developed "rules" that the manufacturer uses when designing special configurations not part of the standard product. Such special configurations may be associated with unusual incoming or outgoing power connections (such as a large number of power cables per phase), special connections to adjacent equipment (such as power transformers or existing switchgear), or unusual sections such as utility revenue metering sections. The manufacturer has validated these "rules" during design dielectric tests of previous equipment, and uses them to create special arrangements to satisfy the ever-changing requests of users. Since these "rules" have been validated during previous design tests, it is not necessary to conduct new design dielectric tests each time a special arrangement is created.

The standards also specify that dielectric ratings apply under standard conditions (temperature = 20 C°, pressure = 101.3 kPa [14.7 psi], absolute humidity 11 g/m³). Of course, standard conditions seldom if ever occur during testing. Therefore, the required voltages during testing must be corrected to adjust them to match the actual test conditions and equate them to the performance at standard conditions.

The requirements of the standards are intended to produce test conditions and parameters that are repeatable and are less likely to be affected by the choice of a particular test laboratory.

During dielectric testing, the equipment, conductors and insulating members must be clean and uncontaminated. The result is that the tests demonstrate the performance under "ideal" (and repeatable) conditions, and performance in the installation site will not match the values obtained during design tests.

Various standards and application guides recognize this, and specify that a "protection margin" be used in insulation coordination studies. This attempts to reconcile the rated dielectric values to the actual capabilities of the equipment in real installations, where the insulation may be degraded by age, atmospheric conditions that are not "ideal", the equipment and the insulating surfaces that are not clean, and other factors. Some documents suggest a protection margin of 15 percent, but the guide for application of metal-oxide surge arresters, IEEE C62.22, indicates factors from 15 percent to 30 percent depending on application, the most common value mentioned being 20 percent.

Some readers may ask about the clearance requirements in the IEEE C57 series of standards, such as C57.12.00 (power transformers) or C57.19.01 (transformer bushings) or similar standards. These standards state required clearances for conductors exposed to the weather, such as bushings on power transformers. Therefore, these applications involve exposure to rain, snow, and other influences. Accordingly, these standards not only specify dielectric tests levels but also specify minimum clearances with due consideration to the environmental effects.

Conversely, the environment of conductors inside metal-enclosed or metal-clad switchgear, or inside medium-voltage motor control centers, is treated as an indoor environment not subject to rain or snow inside the enclosure. This is the reason that standards for conductors exposed to the weather do not apply to conductors inside metal enclosures.

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