

TechTopics No. 116

Arc-resistant switchgear – accessibility type C

This issue of TechTopics continues the discussion of accessibility types for arc-resistant equipment from TechTopics No. 70, discusses the hazards associated with an arcing event, and explains Siemens opinion that type 2C accessibility does not provide an increased level of protection for personnel over that provided by equipment qualified as accessibility type 2B.

Equipment that has been qualified in accordance with the internal arcing tests established in IEEE Std C37.20.7¹ is intended to provide a degree of protection to personnel against some of the hazards associated with an internal arcing event. An arcing fault presents many hazards, amongst which are:

- Extremely high temperatures
- Rapid and dramatic atmospheric pressure increases
- Airborne exhaust byproducts (vaporized materials such as steel, aluminum, and copper, as well as gaseous byproducts of exposure of insulating materials to the arcing in air)
- The potential for ejection of loose parts (shrapnel) and other materials
- Extreme noise levels.

As discussed in TechTopics No. 70, IEEE Std C37.20.7 defines two basic accessibility types: 1 and 2. Type 1 accessibility indicates that the equipment has arc-resistant functionality at the front of the equipment only. Type 2 accessibility indicates that the equipment has arc-resistant functionality at the front, both sides, and the rear of the equipment.

In addition, the standard defines accessibility type modifiers (suffixes) to the arc-resistant accessibility types, A, B, C, and D. Suffix A applies when no other suffix applies and is relevant to all arc-resistant equipment. Suffix B applies to equipment that maintains arc-resistant functionality when the door of the low-voltage control or instrumentation compartment is temporarily open.

Suffix C is for equipment in which arc-resistant functionality is maintained among compartments internal to the equipment. Suffix D applies only to type 1 equipment where one or more of the enclosure surfaces is excluded due to inaccessibility to personnel.

Many years ago, the concept of an accessibility modifier C originated in Canada, in which an arc originating in one compartment is not allowed to migrate into adjacent compartments, i.e., as from one circuit breaker compartment to another adjacent circuit breaker compartment, or from one circuit breaker compartment to an adjacent voltage transformer auxiliary compartment. It was probably not intended to provide increased protection to personnel, but over time, many users seem to have formed the perception that accessibility type 2C provides greater protection to personnel than accessibility type 2A or 2B.

Equipment qualified as arc-resistant is intended to prevent significant escape of gases in the areas where personnel might be present. When an internal arcing test is conducted in accordance with the IEEE Std C37.20.7 standard, the areas in which personnel might be present are evaluated with flammable cotton indicators placed 100 mm (four inches) from the vertical surfaces of the equipment up to a height of two meters (79 inches) and horizontal indicators placed at a height of two meters in the area 100 – 800 mm (4 – 31.5 inches) from the enclosure.

These indicators are not allowed to ignite as a result of an internal arcing fault, with few exceptions, such as indicators that ignite as a result of a label on the equipment burning and falling off of the equipment into contact with the indicator. While there is no precise correlation, as yet, between the energy necessary to ignite the cotton indicators and incident energy, the functional intent is that the internal arcing tests roughly correspond to an incident energy exposure of 1.2 J/cm² that is accepted as the threshold of a curable burn in IEEE Std 1584 calculations.

So, arc-resistant equipment provides a degree of protection against the thermal effects of an arcing event, by channeling arcing exhaust gases out of the equipment away from the areas in which personnel might be located.

But, in the listing of hazards given earlier, the thermal hazard is only one of the hazards associated with an arcing event. What about the others?

The noise associated with an arcing event probably gives rise to the phrase "arc blast", as the noise is somewhat like that of an explosion. Experiments conducted by Richard Doughty and Dr. Thomas Neal² reported sound levels that greatly exceeded the impact or impulsive sound pressure (noise) limit established by OSHA⁷ of 140 dB, even for relatively moderate fault levels^{4, 5, 6}. Their research also indicated that there is no safe time duration for exposure to such extreme sound levels, i.e., that hearing damage is virtually assured. With arc-resistant equipment, much of the sound pressure would be attenuated by the enclosure, but by no means all of the sound pressure. As a result, unless hearing protection is used in the vicinity of energized electrical equipment, severe hearing damage is likely to occur³.

Another major hazard associated with arcing is due to rapid pressure increases. Arc-resistant equipment is designed so that the outer envelope of the equipment stays intact to prevent hot gas escape, which has the effect that pressure is not placed directly on personnel although personnel in the area around the equipment would certainly feel the significant pressure rise in the room and might perhaps feel uncomfortable. Internally to the equipment within adjacent compartments, this uncomfortable feeling would be dramatically increased as the compartment walls would transmit the reduced pressure waves as they act essentially as drums. This action would expose any personnel inside the compartment to increased pressures and any harmful effects. Additionally, as the sheet metal bulges due to the pressure increase resulting in distortion of the adjacent compartments, the potential for physical injury due to shrapnel or the reduction of space within the compartment is also increased.

Exhaust gases contain potentially hazardous materials and chemicals, including vaporized metals, decomposition products of insulation exposed directly to the arc, vaporized paint, and a number of other materials. If the equipment includes an exhaust plenum (exhaust duct) to direct the exhaust products outside of the equipment room to an area from which personnel are excluded, much of this hazard is mitigated. However, the procedures defined in the IEEE Std C37.20.7 standard do not evaluate this hazard and inside the confined space of an internal compartment, where significant exposure would be unavoidable.

The high temperatures associated with an arcing event have been discussed, but only in the context of the areas of the arc and the exhaust stream. But, when an arc occurs inside an enclosure, the sheet metal surfaces of the compartment in which the arc occurs will experience a rapid and significant rise in temperature.

Contact with the sheet metal surfaces of such a compartment during, or shortly after the occurrence of an arcing event, would expose an operator to very high temperatures with the potential for injury. Very little is known about these temperatures, other than that the paint on such sheet metal is usually discolored and the metal itself is often distorted but otherwise intact.

In summary, if a person were inside a compartment performing work adjacent to a compartment that experienced an internal arcing event, that person will likely experience temperatures high enough to result in injury. Certainly, the noise from the arcing event, occurring on the other side of a metal side wall, would likely cause hearing damage and the pressure increase and gaseous vapor entry in the compartment would expose that person to a myriad of potential hazards. Beyond that, there would be a great potential for traumatic stress. Altogether, Siemens is led to conclude that a person should never be working in an open compartment of energized electrical equipment, even if the equipment is qualified as arc-resistant.

Some users specify accessibility type 2C to the IEEE Std C37.20.7 document, thinking that the construction will reduce the potential hazard risks making it safe to work inside the compartment adjacent to the compartment in which the arcing event occurs. The discussion in this issue of TechTopics should illustrate that the hazards to personnel working inside a compartment adjacent to one in which an arcing event occurs are only partially addressed by the tests defined in the standard. As a result, the working group for the original creation and subsequent revisions of the standard considered seriously not including type C accessibility in the document. It was finally included only because of the potential for widely varying test protocols that would result if C37.20.7 did not standardize the requirements.

As discussed in this issue of TechTopics, Siemens is of the opinion that accessibility type 2C does not provide an increased level of protection for personnel as compared to the level of protection provided by accessibility type 2B. There is some thought that if an arcing event occurs in equipment that is qualified as accessibility type 2C, the damage to the equipment (and hence, the time to restore the equipment to usability) will be reduced. This may be the case with low-level arcing events, but it is doubtful it is real with arcing faults that approach the ratings of the equipment. In arcing events, the sheet metal of the enclosure is distorted in the direction of the adjacent switchgear compartments. This distortion may be sufficiently severe to make it necessary to replace or reconstruct the adjacent compartments so that their functionality is restored. This is particularly the case when the adjacent compartment is a circuit breaker compartment as the enclosure may be distorted to the point that secondary disconnects, racking mechanisms, mechanically operated switches and the like would no longer function correctly.

Several vendors indicate that they can provide equipment with accessibility type 2C, but they do not provide the details to understand what they can (and more importantly, what they cannot) do.

Sampling of competitive information indicates that:

- Some vendors claim to offer type 2C if the equipment does not have stacked circuit breaker cells, and with restrictions on arrangement of auxiliary (VT, CPT or CPT fuse drawout trays) equipment.
- If circuit breakers are stacked, no known vendor can offer type 2C for the entire equipment including the rear cable connection compartments. For such designs, the lower cable compartment cannot exhaust arcing byproducts and gases except through the upper cable compartment, and hence, cannot be type 2C in the rear.
- Similar logic applies to drawout auxiliary compartments, such as for VTs, CPTs, or CPT fuses. Typically, vendors who can offer two drawout auxiliaries in a circuit breaker sized cell of non-arc-resistant equipment have to restrict auxiliaries to one drawout auxiliary compartment per circuit breaker sized cell.

In summary, the benefits of type 2C accessibility are illusory. Even the claimed benefit of reduced downtime to rebuild a section that has experienced an arcing fault is not real, and no claim of increased safety for personnel is valid. Type 2C only relates to the equipment, not to safety of personnel, as no personnel safety benefit is provided beyond that provided by equipment of type 2B accessibility.

References:

1. ANSI/IEEE Std C37.20.7-2007, "IEEE Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults," IEEE (<http://standards/ieee.org>)
2. R. L. Doughty, Dr. T. Neal, T.A. Dear, and A. H. Bingham, "Testing Update on Protective Clothing & Equipment for Electric Arc Exposure", IEEE Petroleum and Chemical Industry Conference, Sept., 1997.
3. ANSI/IEEE Std 902-1998 (the "IEEE Yellow Book"), "IEEE Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems, IEEE (<http://standards/ieee.org>)
4. "Arc Flash Hazards, Incident Energy, PPE Ratings & Thermal Burn Injury – A Deeper Look", T. Gammon, W. Lee, Z. Zhang, B. Johnson, IEEE IAS Electrical Safety Workshop, Louisville, 2015.
5. "Testing update on protective clothing and equipment for electric arc exposure", R. L. Doughty, T. E. Neal, T. A. Dear, and A. H. Bingham, IEEE IAS Magazine, V5, no. 1, Jan/Feb 1999.
6. "Shrapnel, pressure, and noise", T. E. Neal, R. F. Parry, IEEE IAS Magazine, V11, no 3, May/June 2005.
7. 29CFR 1910.95(b)(2), Table G-16, footnote (1) www.osha.gov.

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