

TechTopics No. 81

Arc-flash incident energy mitigation

The issue of arc-flash incident energy has grown significantly in recent years as users and specifiers have become more aware of electrical safety. Occupational Safety and Health Administration (OSHA) regulations, National Fire Protection Association (NFPA®) standard NFPA 70E®, and technical papers presented in IEEE publications and conferences, as well as other venues, have increased this awareness.

As a consequence, design engineers are actively working to design systems so that the maximum arc-flash incident energy of their systems will not exceed a particular value. This is generally correlated to the ratings for arc-flash protective clothing and the hazard/risk categories (HRC) in NFPA 70E. HRC category 3 personal protective equipment (PPE) must have a minimum arc rating of 25 cal/cm², while HRC category 4 PPE must have a minimum arc rating of 40 cal/cm².

Engineers have begun to specify limits for incident energy in their equipment purchase specifications. An example of such a requirement follows:

“The medium voltage arc-resistant switchgear shall be designed such that it will mitigate arc-flash hazards to a maximum of 25 cal/cm² (HRC category 3 arc rating) in accordance with NFPA 70E.”

The switchgear manufacturer cannot comply with such a requirement, because it demands performance that depends on many factors over which the switchgear manufacturer has no control.

When equipment furnished is qualified as “arc-resistant” switchgear by design testing to the requirements of IEEE Std C37.20.7, there is no problem with a limit, such as 25 cal/cm², provided that the equipment is in its arc-resistant condition, and assuming that the duration of the arcing event is no greater than the rated duration of 0.5 s, regardless of the location of the arcing fault inside the arc-resistant equipment.

The latest revision of NFPA 70E recognizes reduced PPE requirements for arc-resistant switchgear for certain operations when the equipment is in its arc-resistant condition.

Recent technical literature is rich with papers on the subject of arc-flash incident energy calculation, primarily using the techniques presented in IEEE Std 1584. From these papers, the calculation of incident energy involves multiple factors, including:

- The magnitude of bolted fault current
- The design of the protection system, including arc-sensing systems
- The duration of the arcing current
- The working distance from the arc
- The system configuration (for instance, tie circuit breakers closed or alternate sources connected)
- Whether or not the equipment is in its arc-resistant state (all doors and panels correctly closed and secured, equipment correctly installed, as required by IEEE Std C37.20.7).

A switchgear supplier has no control over any of these critical factors. The switchgear manufacturer does not determine the bolted fault current and cannot reduce it. Similarly, the equipment vendor does not specify the protection relays or configuration. The switchgear supplier does not determine – nor can the supplier enforce – any particular protective relay settings, most especially the time delay from fault inception to the sending of trip signals to all sources of power. Lastly, the equipment supplier has no control over the working distance.

Since the factors that determine the amount of incident energy cannot be controlled by the switchgear manufacturer, claims cannot be made that incident energy will be limited to a particular value. This is a shared responsibility between the consulting engineer or designer, and the owner or operator of the equipment. The consulting engineer is responsible for determining the incident energy for various operating scenarios and for determining the protective device settings and operating procedures, and it is the responsibility of the owner or operator to maintain the system, adhere to the specified settings and scenarios, and to update the studies when system conditions change.

Arc-detection schemes

It is desirable that arc-resistant equipment employ protection means to detect an arcing fault within the equipment, and to rapidly initiate tripping of all sources of power to the arcing fault, preferably well under the rated arcing duration of 0.5 s (refer to IEEE/PES T&D Conference paper, "Strategies for Mitigating the Effects of Internal Arcing Faults in Medium-Voltage Metal-Enclosed Switchgear" for discussion).

Typical protection schemes used for this purpose use light sensing to detect the presence of an arc, with simultaneous current sensing to provide security (assurance of a correct "trip" decision), rather than relying on the presence of light alone. Traditional bus differential protection can also be quite effective in detecting not only an arcing, but also any other kind of fault inside the bus differential zone of protection.

Today the most common scheme employs light sensors, so the rest of the discussion will focus on equipment that uses light sensing to detect the presence of an arc and to initiate tripping of all power sources.

If an arcing event is initiated but is not located inside the zone of protection of the light detection system, as for example, an arc on the line side of a main circuit breaker and on the line side of the current transformers, even if the light emitted by an arcing fault is detected, the sensing system will not send a tripping signal to all sources of power. This is due to the design of the light sensing system, which requires not only that light be sensed, but also that there be confirmation by simultaneous current in the protected circuit.

If the fault is on the line side of the current transformers, the sensing system will not see current and tripping will not be initiated. Even if the system does not have the security feature of requiring a confirming current signal, if the fault is on the line side of the main circuit breaker, tripping of the main circuit breaker would not remove the fault.

NEC 110-16 field marking for potential arc-flash hazards

The subject of limiting arc-flash incident energy to a fixed value situation described in this issue of TechTopics is similar to the requirement in the National Electric Code® (NEC®) (NFPA 70®), article 110-16 that requires that electrical equipment be field marked to warn of potential arc-flash hazards. Code-Making Panel no. 1, responsible for article 110, recognizes that the equipment manufacturer cannot mark the equipment with the incident energy exposure as the manufacturer does not have the required information and cannot control future changes to the conditions under which the incident energy is determined.

References:

- NFPA 70E, "Standard for Electrical Safety in the Workplace"
- NEC NFPA 70 National Electric Code
- OSHA regulations, 29 CFR parts 1910 and 1926
- IEEE Std C37.20.7, "IEEE Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults"
- IEEE Std 1584, "IEEE Guide for Performing Arc-Flash Hazard Calculations"
- "Strategies for Mitigating the Effects of Internal Arcing Faults in Medium-Voltage Metal-Enclosed Switchgear," co-authors include T. W. Olsen. 2001 IEEE/PES Transmission and Distribution Conference and Exposition, (Conference Paper) Cat. No.01CH37294.

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