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Addressing the Dangers of Arc Flashes

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by Charles Hoes

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The hazards and risks associated with arc flash have been on my mind for the past couple of years. It would seem that the issue is pretty simple and straightforward, but the more I consider it, the less obvious it becomes.

The topic was completely off my radar until about three years ago, and at first, I ignored it because it didn't seem to apply to projects I was working on. Wikipedia has the following definition for the term: "An arc flash is a voltage breakdown of the resistance of air resulting in an arc which can occur where there is sufficient voltage in an electrical system and a path to ground or lower voltage. An arc flash with 1000 amps or more can cause substantial damage, fire or injury. The massive energy released in the fault rapidly vaporizes the metal conductors involved, blasting molten metal and expanding plasma outward with extreme force. The result of the violent event can cause destruction of equipment involved, fire and injury not only to the worker but also to nearby people.



"In addition to the explosive blast of such a fault, destruction also arises from the intense radiant heat produced by the arc. The metal plasma arc produces tremendous amounts of light energy from far infrared to ultraviolet. Surfaces of nearby people and objects absorb this energy and are instantly heated to vaporizing temperatures. The effects of this can be seen on adjacent walls and equipment — they are often ablated and eroded from the radiant effects." I believe the Wikipedia definition has one rather large flaw, and that is the reference to more than 1000 amps. This problem can exist at currents far below that.

If this sounds pretty dramatic, it is. NFPA 70E has a long section and an appendix devoted to this topic. Unfortunately, this standard seems to raise more questions than it answers, leaving me wondering just how to properly address the issues involved.

The first question that comes up is, "When can this problem exist?" It's my understanding that it can happen whenever an arc is created during "hot work" (work on energized conductors) if sufficient current is available. It can start as a small spark, which creates a low resistance path through the air (an arc), which rapidly grows to an intense arc — causing the explosion and flash described in the Wikipedia definition. Since most industrial operations use Lockout Tagout (LOTO) procedures to ensure that work is not performed on high-current conductors, it might seem that the issue does not

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exist. However, part of the procedure is to make a voltage measurement to verify that the circuit is actually dead. This implies that it might not be dead; therefore, this might, in fact, be hot work and might draw an arc, which could precipitate a lethal arc flash explosion! So, the very act of implementing a LOTO procedure might well be creating the hazard. It is also possible for this to occur at random because of the failure of components or insulation, or accidental shorting between conductors. Any time there are exposed high-current carrying conductors, it is a possibility, especially when associated with switchboards and panel boards.

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Some, but not all, electrical panels are designed to withstand the forces created by an arc flash explosion. In some instances, protection is provided if the panels are closed, but that protection does not exist if the panel doors are open. Therefore, it is a possible hazard whenever a person is near a high-current panel board, electrical panel or switch board. This is a bit of a problem in that it is ubiquitous in many industrial environments. NFPA 70E implies that the hazard exists for all electrical circuits above about 100 volts and unspecified amperage — presumably quite low. (This whole discussion only applies to "power circuits," not to circuits that are inherently current-limited such as in the old automobile coils, where there were tens of thousands of volts but very little current capabilities.)

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Addressing the Dangers of Arc Flashes

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by Charles Hoes

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The first line of defense proposed by NFPA 70E is to provide specifications for Personal Protective Equipment (PPE) based upon voltage. The idea is that the higher the voltage, the higher the potential current and thus the greater the energy available in an arc flash. The NFPA document provides tables that define the limits of the radiated energy at 18 inches from the flash point to levels that will not cause severe burns. However, that does not apply to portions of the body within 18 inches. Therefore, even if the available energy is less than that requiring PPE, according to the tables, there may still be a need for PPE for body parts within the 18-inch range. Not only that, but the specified PPE is for the radiation hazards; it does not address the impact hazards associated with the explosive forces or the spray of molten metal that may result from the flash. While this table is interesting, it is of limited usefulness because it relates the PPE requirement to voltage, rather than to available energy, which is, of course, the real issue.

There is also a small table describing levels of PPE protection versus arcing energy. This is a more useful table, but it raises the question of how to determine the energy available in a flash. The first thought might be that the current (and thus the energy) would be limited to the tripping current of protecting fuses or circuit breakers. Unfortunately, this is not the case because the arc flash hazard develops very rapidly, far faster than fuses or circuit breakers can offer protection at the tripping current. Tens of thousands of amps can flow through a 100-amp circuit breaker before the breaker has time to trip. (In fact, a bolted short-type fault can result in currents so high as to cause the breaker to explode if the entire chain of protective devices is not properly coordinated, but that is a topic for another time.) So if the tripping breaker is not capable of limiting the energy, what can we do to ensure adequate safety?

Appendix A in NFPA 70E has an interesting example describing how to address the problem of finding a "reasonable" arc energy. It is based on the fact that certain types of commonly used circuit breakers have additional tripping devices built into them, and that they contain mechanisms that cause them to trip at much higher currents, and much faster than the elements used for the rated tripping currents. The maximum arc current/energy can be calculated, given the breaker type and voltage. I ran through these equations for breakers used in a project that I am working on that operates at about 400 volts AC. In doing this, I discovered that 600 amps is about the limit for requiring PPE at 18 inches in accordance with the PPE tables. My conclusion is that if the facility breaker (supply breaker) is less than about 600 amps, then PPE protecting the person's body is not necessary (although some protection is still needed for the hands, which can get much closer than 18 inches from the arcing point). This result limits the need for special PPE (beyond safety glasses and gloves) for most of the electrical panel boards in the factory. However, there are three power drops that have facility breakers larger than 600 amps, which are still a concern.

I brought my analyses to a couple of Underwriters Laboratories-trained electrical specialists to get their opinion of the validity of my results. They said that my approach was worthless and that a much more in-depth and complicated analysis was necessary! The problem is that their approach is so complex and time-consuming that it is unlikely to be funded or performed. I am satisfied that my solution is good enough to give a ballpark answer to when PPE is needed to protect persons from radiative heating. However, it still leaves the question of how to deal with the explosive forces that might be present. I asked a local electrical contractor for his approach to this. He responded that when tripping breakers in a power box, you need to stand aside and only use the hand that you are willing to lose! Personally, I am not particularly willing to lose either one.

It seems to me that a clear approach to providing arc flash protection is still a work in progress. I have heard that special circuit breakers are being produced that more reliably limit the high-fault

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currents than older versions. I have suggested that maybe voltage measurement devices for checking LOTO could be built into the power boxes, allowing verification without opening the box. So far, this suggestion has been rejected by my customers. Power boxes and panels should be designed to withstand internal explosions, but at this time this is not included as a design requirement. Some power boxes seem to be strong enough to withstand the explosive forces, but this is because of other considerations, not because they were designed to withstand arc flash forces. Addressing this entire question in a comprehensive and thorough way is an opportunity for much additional research and development work. 

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