An Opinion Paper

by
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I've always used bolted fault current as my input current for ARCPRO; however, as a rule I do not use ARCPRO for secondary faults (below 1000 volts) except to see where I might be compared to IEEE 1584.

At higher voltage Heuristic Analysis tells me that there will be minimal difference between arc current and bolted fault current values especially as an arc matures. In an email Steve Cress of Ontario Hydro stated, "For a high voltage system it would not be unreasonable to use the bolted to approximate the arcing current" and I agree.

In performing Arc Flash Calculations I try to keep in mind that at their best; they are an approximation and much less accurate (my opinion) than bolted fault current calculations and certainly less precise than load calculations.

There have been at least five methods put forth for estimating the Arc Flash Hazard; only two are currently broadly accepted - IEEE 1584 and ARCPRO.

IEEE 1584 provides a method for estimating arc current, ARCPRO does not. NFPA 70E never did. Each method has stated limitations. ARCPRO's User Guide (page one, second paragraph) states "***The ARCPRO program calculates the thermal parameters associated with an electric power arc aligned vertically in air. The program does not consider arcs in any other physical configuration, it does not perform computations for multi-phase arcs, nor does it account for arc movement***." Experience tells us that this is not what happens under field conditions, arcs move and expand sometimes including all three phases, heated air rises and electrodes vaporize increasing arc length,

Page two, paragraph two, of the ARCPRO User manual states "***Energy and heat values computed by ARCPRO have been verified by comparison with measured results from high current laboratory tests involving controlled vertical arcs in air. ARCPRO results have shown good agreement with measured values from a series of tests covering the following ranges of parameters: currents from 3.5 kA to 21.5 kA, arc durations from 4 cycles to 30 cycles, arc lengths from 1 inches to 12 inches, and distances of 8 inches to 24 inches from the arc.***

The use of ARCPRO for estimating the arc hazard on typical electric supply system construction immediately becomes an engineer's "best guess" because situations where we have arcs "aligned vertically in air" are at best very limited. Overhead open air secondary are aligned horizontally; meter boxes or canisters, panels and transformer secondary compartments are boxes and enclosures. ARCPRO has not been validated under these conditions only in open air.

Testing performed by Malcolm Smoak, PE of SWEPCO, Shreveport, Louisiana and presented to Sub Committee 8 of the NESC® in 2008 showed that voltages of 240 volts or less will not sustain an arc across a 1/10" gap for more than ½ cycle. With this in mind why would I calculate the hazard other than for verification that I do not have a hazard? Overhead secondary spacing is larger than 240/120 volts arc current can bridge and therefore if a hazard exists, can it not be mitigated by work practices? Voltages of 480/277 and 240/480 are another matter.

History – Ralph Lee of DuPont and Nomex fame first described the hazard in a 1981 – 82 paper titled "The Other Electrical Hazard". The paper provided a methodology for calculating radiate heat from an electrical arc. In 1995 NFPA 70E published Dr. Lee's equation in Appendix "B" and used bolted fault current values.

NFPA 70E 2000 expanded Appendix "B" including equations presented in an IEEE paper authored by *"R. L. Doughty, T. E. Neal, and H. L. Floyd, II, "Predicting Incident Energy to Better Manage the Electric Arc Hazard on 600 V Power Distribution Systems," Record of Conference*

Papers IEEE IAS 45th Annual Petroleum and Chemical Industry Conference, September 28-30, 1998." These equations also used bolted fault currents and were limited to bolted fault currents "for the range of 16 to 50kA", voltages of 600 volts or less and for worker distances of 18 inches or more.

In 2002 IEEE 1584 and for the first time Arc Current began to be used to calculate the arc hazard. The ARCPRO Users Guide I possess indicates copyrights of 1995 and 1998 both of which precede IEEE 1584 and the ARCPRO users guide offers no guidance or information on how one should estimate the magnitude of current in an arc.

Marcia Eblen, PE of PG&E (California) who has conducted extensive testing on 480 volt equipment and has compared her testing with IEEE 1584 calculations, expresses satisfaction with the correlation at this voltage level. The brief review I have given her material in my opinion substantiates her findings.

IEEE 1584 states in section ***7.2 Theory based model*** *"Ralph Lee [B19] developed a theory based model of the arc flash. It served for many years as the only method available. Its biggest limitation is that it does not include a method of finding arc current, which is very important for cases under 1000 V. It also does not consider magnifying effects of arc in a box. For applications greater than 1000 V, it is quite conservative. This method is included in this guide and in the calculators for applications where the empirically derived model is not suitable, such as those in open air substations, and open air transmission and distribution systems."* This statement tells me to not use IEEE 1584 for overhead distribution work where the probability of a three phase arc is minimal and that if I use Ralph Lee's formulae I should expect a conservative number but not how conservative. And I see nothing that would make me want to use either Lee's Method or 1584 for transmission level voltages. I also note that 1584 lets us off the hook on finding arcing currents for arcs above 1000 volts.

Consequentially I have arrived at the following conclusions:

1. Use IEEE 1584 for both single and three phase faults on circuits energized at 1000 volts or less.
2. Use ARCPRO on all open air arcs above 1000 volts.
3. Use bolted fault current values for all inputs.
4. Adjust for slowing clearing times using larger time values.
5. Adjust for arcs occurring in cubicles energized at voltages 1000 volts or more by a factor of 2.
6. For all situations analyze to determine if alternate work practices/methods will mitigate the hazard to a safe level w/o undue layers of PPE.

Adding an engineer's woes when performing arc flash analysis is the fact that recent testing is indicating that when convective heating is measured, our clothing FR rating values may be over rated by a factor of two (2).

The short version of this story is industry does not definitively possess adequate information to predict with 100 percent certainty what a worker may encounter in an arc flash incident. Doing nothing is unacceptable. Consequently we use what we have and constantly look for improved methodology. Remember FR rated PPE is a form of fire insurance that we hope is never needed. We can do that by enforcing existing safe work practices and procedures. Workers and engineers should take note that no clothing manufacturer has printed a large red "S" on the chest of their garments.