70E Table Method Analysis

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Introduction

The current “gold plated” standard for arc flash hazard analysis is IEEE 1584. To date, no “failures” of this standard have occurred. There have been incidents where buns have occurred but IEEE 1584 suggests that it should protect against a 2nd degree or greater burn injury to the face/chest area at least 90-95% of the time. The negative to using the IEEE 1584 empirical method in particular is the large amount of data gathering and the fairly expensive and time consuming power system analysis that is required to produce valid results.

In some cases, the results of such an engineering approach as using IEEE 1584 or similar methods is not available. In those cases, the alternative is to resort to a table such as the tables in NFPA 70E or the tables in IEEE C2 (NESC). A caveat to use of either table method is that there are a series of assumptions given which can only be verified through substantially the same amount of effort as the engineered approach contained in IEEE 1584. Since IEEE 1584 is the “gold plated” standard, there is no value in using the tables as provided. The alternative is to eschew the footnotes in the tables in NFPA 70E and to simply use the equipment and PPE tables as-is without regard for the footnotes limiting the fault current and opening time values. This approach flies in the face of the tables but recognizes that an engineering analysis may not be available or the purpose of wearing PPE is in the steps necessary to prepare such an analysis. This would be the case for instance where contractors are working at a host site that has not performed the analysis or when the initial analysis is being done on existing equipment.

Numerous claims both for and against this approach have been made. For instance a representative of the Arc Advisor commercial software site has vehemently denounced this approach as unsound on the basis that it throws the clear engineering requirements in the standard to the winds. An even more controversial counter claim has been made that the majority of the protective value of arc flash PPE is in the fact that the fabric does not propagate a flame and that the thermal value is of lesser importance. In “Flame resistant textiles for electric arc flash hazards”, Hoagland makes the following statement:

> “Arc-rated clothing has two different uses in industry: non-contributory uses and protective uses. The most critical use is the non-contributory. One study has indicated that clothing ignition may create most of the injuries in electrical incidents (Kent and Floyd, 1995). While shock is still the most frequent electrical killer, when shock does not kill, clothing may cause most of the injuries due to its ignition from arc flash exposure. One paper has pointed out that most arc fl ash incidents which do not have clothing ignition result in <25% body burn (Doan, Hoagland and Neal, 2010). This fact means that prevention of ignition provides most of the benefi ts of arc flash protection in survivability.”

Interstingly the latter paper is referenced above, “Update of Field Analysis of Arc Flash Incidents, PPE Protective Performance and Related Worker Injuries”, IEEE ESW2010-15 or the previous version of

the paper. Such a statement does not exist but a collection of data on various incidents does exist within that paper. A single high level pie chart is given in that presentation along with an extensive table of arc flash incidents that were meticulously collected from multiple sources.

Method

The cases in the Doan, Hoagland, and Neal paper will be reanalyzed to try to draw some conclusions about the likelihood of an injury if an arc flash occurs by using the tabular method in 70E-2015. Out of 54 total cases, 3 are high voltage (over 35 kV) for which there is no way to verify anything about the results. These three will not be considered further, leaving a total of 51 cases.

The data will be analyzed in spreadsheet form considering the following:

1. The analysis method used (when given).

2. The type of equipment which is used by NFPA 70E. When the equipment is given only as “switchgear”, 600 V class gear is assumed.

3. Whether 2nd degree or greater burns occurred to the face/chest area, and whether any burns occurred at all.

4. Whether PPE given complied with IEEE 1584 standards for the body and head (two separate criteria) as well as the same criteria applied to NFPA 70E-2015 tables.

5. Whether the clothing ATPV rating required in the NFPA 70E tables meet or exceed the incident energy estimate.

6. Whether the PPE is arc rated over both the body and head areas.

7. Analysis of yes/no columns are given as numerical results where 1=yes and 0=no to facilitate numerical calculations.

Analysis

52% of the reported cases resulted in a burn injury. However, only 25% of the cases resulted in a 2nd degree or more severe injury to the face or chest area. This matches Hoagland's 25% claim but includes cases in which both arc rated and non-arc rated PPE was in use. Since IEEE 1584 and other standards are designed specifically with this threshold in mind, the remaining 27% of cases should be considered a success even if a burn occurred using IEEE 1584 or NFPA 70E as the standard. In cases where IEEE 1584 or P1584 is given as the analysis method and PPE is worn to meet those criteria (5 cases) a burn outside of the face/chest area occurred only once and no burn injuries at all were received in the other 4 cases. Note however that in many of these cases it is likely that the bun injuries sustained did exceed 25% of the total body surface area and so may be considered life threatening. Further analysis than this cursory examination is in order.

70E tables are mentioned as the analysis method in only 6 of the 51 entries. Of those, no head protection was used in 5 cases . However since this data stretches back pre-2012 when head protection was required for most circumstances, this was not unusual at that time. Also pre-2015 standards, under-rated PPE was allowed during tasks where a reduction in likelihood was used as justification for reduced PPE, despite the fact that PPE was still required and the magnitude of the hazard was not reduced. In 70E-2015 and later this analysis was corrected to a simple binary decision (whether or not PPE is required). In the single case where full head and body protection was worn, no injury occurred. When body but not head protection was worn (1 case), no injury occurred. When neither was worn to meet that standard (4 cases), injuries including second degree or more severe to the face/chest area occurred. In all cases, PPE would have also matched the IEEE 1584 recommended level of arc flash protection as well when it was worn. Thus in a single case where full NFPA 70E compliance with the tables was used, no injury occurred.

With so few test cases, another approach is to look at whether or not the tabular method provides adequate protection compared to the engineered method. Without consideration for the PPE actually worn the NFPA 70E table method recommends PPE that meets or exceeds IEEE 1584 incident energy estimates 43 times (84%). However out of the 8 cases under-rated PPE was worn in only one case (case #5) and no injury occurred. Thus in the solitary case where this occurred, success rate was 100%.

Adequate PPE (by IEEE 1584 standards) was worn only 25% of the time. Of those instances, a burn injury outside of the face/chest area occurred only twice (15%) which is not meant to be addressed by the standard in the first place and no injuries occurred to the face/chest area exceeding 1st degree burns (100% success). Conversely without adequate PPE, 2nd degree or greater burn injuries to the face/chest area occurred 43% of the time and burn injuries overall occurred 90% of the time. It should be noted that standards using IEEE 1584 do not increase the thermal protective values for arms and hands that are typically much closer to an arc so IEEE 1584 should be expected to allow burns outside the face/chest area, particularly the hands and arms. Since burn injuries without adequate PPE occur 90% of the time, the reduction to only 15% of cases would seem to suggest that IEEE 1584 is overly conservative.

Finally the data set was carefully tallied to consider cases where PPE was under-rated by IEEE 1584 standards but in which the PPE was still arc rated over both the head and body. This is the same criteria set out by Hoagland, the so-called “non-contributory” case. Currently NFPA 70E-2015 mandates use of arc rated PPE whenever arc rated PPE is required. In the analysis under-rated PPE that was still arc rated from head to toe was used in 4 cases. No injury was sustained in those cases.

Combining the results, we may first recognize that in 84% of cases considred, choosing arc rated PPE using the NFPA 70E-2015 tables meets or exceeds the selection that would occur using IEEE 1584. The same results (no 2nd degree or greater injuries to the face/chest area, and relatively minor burns elsewhere in 15% of cases) should occur despite the lack of engineering rigor. In the remaining 16% of cases, no cases were found where arc-rated PPE was worn with body head and body protection where a burn injury occurred. Similarly when PPE meeting NFPA 70E-2015 was worn but was under-rated, no injuries occurred.

Conclusion

It would appear that although the data is limited, the NFPA 70E tabular method would give adequate protection in at least 84% of cases given in the Doan, Hoagland, and Neal paper. In the remaining 16% of cases an injury is still highly unlikely due to the non-contributory nature of the PPE. The “25%” value given by Hoagland can't be backed up except by considering the entire data set which exceeds the criteria given (percentage of injuries where inadequate arc rated PPE is used). However a much stronger case is made in that the data points meeting that criteria provided 100% protection against burns exceeding the IEEE 1584 criteria. Based on the somewhat limited data, the 70E-2015 tabular method should work numerically at least 85% of the time whereas IEEE 1584 claims numerical success approximately 90-95% of the time. In this limited data set both IEEE 1584 and the 70E tabular method work 100% of the time.

Thus however nonscientific the tabular method may be and however nonscientific the preceeding data analysis itself may be, it does lend credence to the idea that perhaps using the NFPA 70E-2015 tabular method while eschewing the obvious engineering analysis required in that method may indeed provide nearly the same level of protection in practice as IEEE 1584 or other similar, competing standards as the tables did not yield any cases in which such an approach would result in an injury greater than that covered by using IEEE 1584 to determine PPE requirements.