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Assessing The Limitations Of Arc Flash Hazard Tables

By Albert Marroquin

Communicating the dangers associated with energized electrical equipment is one of the core elements of any workplace electrical safety program. One of the most vital steps of that process is classifying various tasks according to the Hazard/Risk Category levels listed in NFPA 70E, Standard for Electrical Safety in the Workplace. Understanding these tables is imperative, particularly in Canada, because the forthcoming CSA Z462 Workplace Electrical Safety Standard will be technically harmonized with NFPA 70E.

NFPA 70E Table 130.7(C)(11) uses five Hazard/Risk Category levels for various tasks. These levels range from zero to four. In the CSA Z462 Consensus Draft, dated April 2, 2008, the equivalent table is referred to as Table 5.

As important as it is to understand these tables, it's equally important to understand the limitations of these tables. If these limitations are not considered in your arc flash hazard evalua-

tion, it may lead to selecting an incorrect level of arc flash rated Personal Protective Equipment (PPE), thus jeopardizing the safety of the electrical worker.

Two Alternate Methods To Determine PPE

The most challenging step of an arc flash hazard evaluation is determining how to classify tasks for different electrical equipment types operating at varying voltage levels. Two alternate methods are available for classifying the arc flash Hazard/Risk Category level associated with a particular task.

The first method is to use Table 130.7(C)(9)(a), a "lookup" table that lists different tasks on energized equipment and their associated Hazard/Risk Category levels. In the CSA Z462 Consensus Draft the equivalent table is referred to as Table 4. Although some question the use of Table 130.7(C)(9)(a), there are many situations which require the

use of this table, which we will discuss in this article.

The second method is to have a Professional Engineer in Canada use power system analysis software to conduct a more thorough arc flash hazard analysis. In this case, we recommend using the more rigorous calculation guidelines provided by IEEE 1584-2002 Standard and/or NFPA 70E-2004 Annex D, also Annex D in CSA Z462.

When to Use Table 130.7(C)(9)(a)

As mentioned previously, there are situations which require Table 130.7(C)(9)(a), for example, when it’s necessary to perform emergency work on energized electrical equipment that does not have proper arc flash hazard labels. The table is also useful for determining the required PPE for electrical equipment inspection, such as when an arc flash hazard analysis is necessary and you have to collect electrical equipment nameplate data.

The tables may also be used as part of a simplified electrical safety program for smaller facilities. Take, for example, facilities that use simple radial systems with fewer than 20 buses.

Table 130.7(C)(9)(a) lists and classifies tasks involving such equipment as switchboards, panelboards, Motor Control Centres (MCCs), switchgear and motor starters. For example, the table classifies the “insertion or removal of individual starter ‘buckets’ from MCC” (600V class) as a task with Hazard/Risk Category 3 ($8 < \text{cal/cm}^2 < 25$).

According to footnote 4 of the table, the maximum available bolted short-circuit current limit is 65kA. In addition, the footnote indicates that the maximum fault clearing time (arcing time) should be about 0.33 seconds or 20 cycles.

Validate Results With Power System Analysis Software

You can use power system analysis software to validate the Hazard/Risk Category level the table provides. For example, Figure 1, which uses IEEE 1584-2002, displays a typical MCC configuration with an arc fault simulation at bus MCC-1.

According to IEEE 1584, the simulation uses typical values for gaps (distances between energized bare conductors in mm). Working distance is estimated to be 24 inches (conversely, the NFPA 70E table doesn’t provide arc flash protection boundary or working distances). The MCC has a maximum available bolted short-circuit current of 25kA.

According to the displayed results on the one-line diagram in Figure 1, the program determined a Hazard/Risk Category Level 3 for the faulted location (MCC-1). In this case, the Hazard/Risk Category level agrees with the one listed in the table.

Analysis Software Takes Safety To Next Level

Using power system analysis software, you can perform a different simulation for the same MCC, only this time using the maximum available bolted short-circuit current of 65kA. As you can see from the results in Table 1, the incident energy level could easily reach Hazard/Risk Category 4 or higher simply by using the maximum values of short circuit current.

The results of Table 1 illustrate that the PPE rating suggested by NFPA 70E, Table 130.7(C)(9)(a) may not be adequate for the task. According to IEEE 1584-2002, the typical working distance is 18 inches for a 0.480V MCC. Yet Case 4 shows that the incident energy level for an 18-inch working distance almost exceeds the limit of Hazard/risk Category 4 (40 cal/cm^2).

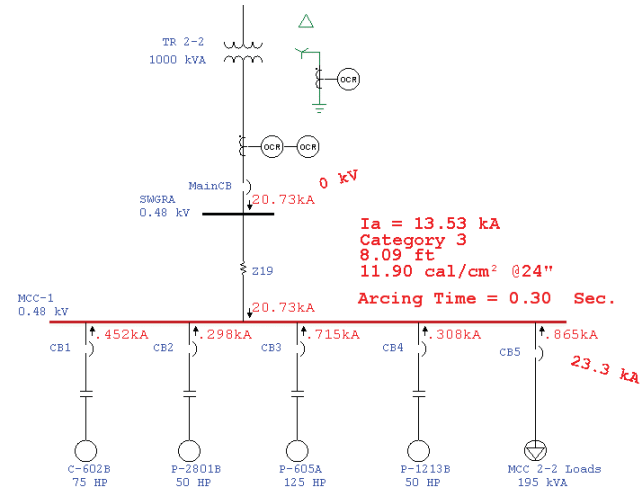


Figure 1. Arc flash simulation for a typical MCC

Case ID	Ibf at Fault Location (kA)	Main Breaker Fault Clearing Time (sec)	Working Distance (inch)	Incident Energy at MCC-1 (cal/cm²)	Hazard/Risk Category
Case 1	23.3	0.300	24	11.9	3
Case 2	23.3	0.300	18	13.81	3
Case 3	64.8	0.300	24	24.31	3
Case 4	64.8	0.330	18	38.98	4

Note: Ibf denotes a bolted 3-phase short-circuit current

Table 1. Incident Energy for a fault at MCC-1 for different working distances

What’s lacking in the NFPA 70E table is the working distance – one of the most dominant factors in the calculation. Even if the available bolted fault current and the fault clearing time stays within the noted limits, the results listed in the table may not provide sufficient protection. Because the table results are generalized, and not specific to a particular system, it is not wise to solely rely on the table to recommend PPE levels on MCCs.

Let’s look at another example for a common task, like energized work on metal clad switchgear above 1kV. According to Table 130.7(C)(9)(a), PPE rated for Category 4 is recommended for the insertion or removal of circuit breakers from cubicles with the doors open.

In this case, we can take a 4.16kV switchgear with typical working distance and conductor gaps based on IEEE 1584 2002 (WD =36 inches and Gap =102mm). Figure 2 exhibits a one-line diagram for typical medium voltage switchgear and the simulated arc flash results for two locations within the equipment.

Incident energy has been calculated for two cubicles. One is a load CB cubicle, which indicates incident energy within Hazard/Risk Category 3 limits. Yet the Main CB cubicle shows a potential incident energy release almost beyond that of Hazard /Risk Category 4.

Although these results are in agreement with those recommended by Table 130.7(C)(9)(a), any variation in the clearing time or bolted short circuit current may cause the incident energy to exceed the levels of Hazard/Risk Category 4. Clearly, the table fails to establish the limits for the bolted fault current.

NFPA 70E Tables vs. A Thorough Analysis

The potential differences between the PPE rating recommended by Table 130.7(C)(9)(a), versus those recommended by the more thorough arc flash hazard analysis, are significant. Table 2 summarizes comparisons made between the NFPA 70E

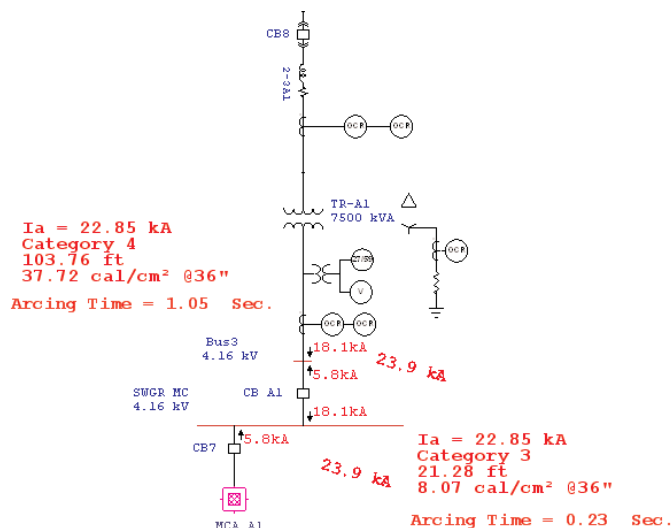


Figure 2. Arc flash simulation for a typical MV switchgear

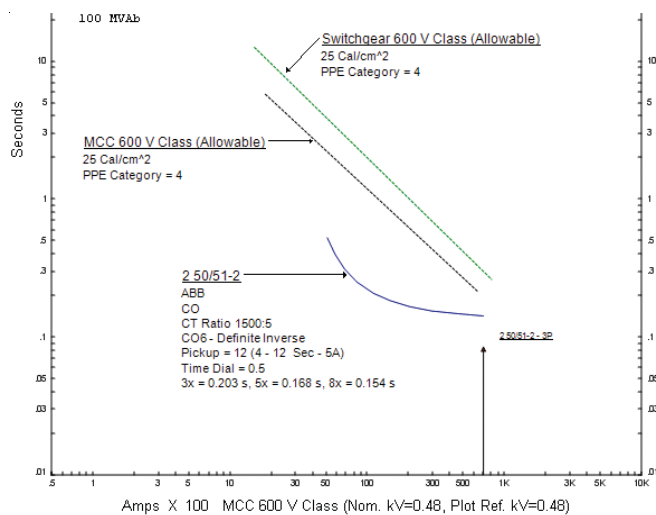


Figure 3. Incident Energy curves for typical LV MCC and Switchgear

table categories against those obtained by the IEEE 1584-2002 method. Please note that this table is not comprehensive and only illustrates a brief summary of a few of the comparisons made for tasks at different voltage levels.

The Hazard/Risk Categories obtained using Table 130.7(C)(9)(a) may be less conservative for tasks expected to be within Hazard/Risk Category 3 and 4 levels. It may be possible to use the table for tasks involving Hazard/risk Categories 0, 1 and 2, as long as the available bolted short-circuit current and arcing time are within the limits specified in the table footnotes.

The comparisons presented in Table 2 demonstrate why performing a thorough arc flash hazard analysis instead of solely relying on Table 130.7(C)(9)(a) is recommended.

Checking TCC Curves

Regardless of the expected task Hazard/Risk Category level, you should always perform a thorough check of the

Time Current Characteristic curves (TCCs) of the protective device expected to clear the arc fault. Variations in the short circuit current levels and clearing times may result in higher arc flash energies. Figure 3 depicts a quick method to check if a combination of bolted fault current and arcing time yield incident energy levels below the PPE rating.

Purple and green curves in the TCC view of Figure 3 represent an incident energy level of 25 cal/cm² for 600V class MCCs and switchgear. The curves were generated using typical working distances of 24 and 18 inches. To yield more conservative results, make sure the example assumes the systems are ungrounded.

The curves show the relationship between bolted fault current and fault clearing time. If the bolted fault current increases, the required clearing time should be less to ensure it doesn't exceed the incident energy level.

According to Figure 3, the right side end of the curves represents the maximum

bolted fault current and corresponding arcing time combination that yields 25 cal/cm² (onset of hazard/risk Category 4 level). An overcurrent relay curve is shown below the incident energy curves.

The bolted fault current is shown below as an arrow. As long as the fault current and the TCC curve are below the incident energy curve, then the incident energy should be less than the allowable limit. A set of curves of this type can be developed for each of the types of equipment listed in Table 130.7(C)(9)(a).

Conclusion

Although it's still necessary to continue the use of NFPA 70E tables under some circumstances, care must be taken to ensure it is only applied under the conditions and limitations stated in the table footnotes. Careful consideration must be given to the effect of variables not listed in the table(s), such as working distances and equipment configuration (grounding and gaps between conductors).

These parameter variations may cause the incident energy exposure to be much larger than the level suggested by the table. That's why the best approach for determining the arc rating of PPE is by having a detailed engineering-based arc flash hazard analysis study completed. ⚠

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Task	Equipment Type	Voltage Level	NFPA 70E Table 130.7(C)(9)(a) Hazard/Risk Category	IEEE 1584 2002 Calculated Hazard / Risk Category	Max Ibf at Fault Location (kA)	Fault Clearing Time (sec)
Removal of bolted covers (to expose bare energized parts)	Panelboard	< 240	1	0	25	0.03
Work on energized parts, including voltage testing	Panelboard Switchboard	> 240	2	0 & 1	25	0.03
insertion or removal of individual starter "buckets" from MCC	MCC	< 600	3	3, 4, & >4	65	0.330
inserting or removal (racking) of CB from cubicles, doors open ²	Switchgear	< 600	3	3, 4, & >4	65	1.000
inserting or removal (racking) of CB from cubicles, doors open ¹	Switchgear	> 1000	4	3, 4, & >4	25	1.05

Note: The IEEE 1584 2002 results were obtained using only typical gaps and working distances for the type of equipment being modeled. The maximum bolted fault current and clearing times are taken from notes 1, 2, 3, 4 & 5.
Note 1: 36 inch working distance. **Note 2:** 24 inch working distance

Table 2. Summary of comparisons made between Table 130.7(C)(9)(a) and IEEE 1584 results on Reader Service Card