DC ARC FLASH. THE IMPLICATIONS OF NFPA 70E 2012 ON BATTERY MAINTENANCE

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Abstract

Arc flash is fairly well understood in ac systems and NFPA 70E [1] provides significant guidance for Personal Protective Equipment (PPE) to prevent arc flash injuries from occurring in ac systems. In the 2012 version of NFPA 70E, new guidance was added that addresses arc and shock hazards for dc systems including storage batteries. This table could have major implications for battery maintenance, especially for UPS applications. This paper carefully reviews the papers and reports used to develop the dc arc flash table and provides practical PPE recommendations for performing battery maintenance tasks. The paper also addresses what PPE is appropriate for battery maintenance activities.

Introduction

The National Fire Protection Association (NFPA) creates several codes and standards to help mitigate fire and other hazards. The most well known NFPA document is NFPA 70[2], the National Electric Code (NEC). The NEC is adopted by most of the jurisdictions across the United States. NFPA also publishes NFPA 70E, which is a Standard for Electrical Safety in the Workplace. NFPA 70E is not a code and is typically not adopted by jurisdictions. However, OSHA considers NFPA 70E to be a recognized industry practice. OSHA also requires each employer to “furnish to each of his employees employment and a place of employment which are free from *recognized* hazards that are causing or are likely to cause death or serious physical harm to his employees”. The aforementioned statement can certainly be used to enforce the recommendations of NFPA 70E since it describes recognized hazards.

IEEE also provides recommended safety practices for stationary batteries. The most notable IEEE recommended practices are IEEE 450 (vented lead-acid batteries), IEEE 1188 (valve-regulated lead-acid batteries) and IEEE 1106 (nickel-cadmium batteries). These IEEE documents all cover maintenance and testing. However, the IEEE documents do not provide guidance on arc flash. Most of the PPE recommendations in the IEEE documents focus on electrolyte safety.

IEEE 1584 is a guide for performing arc-flash hazard calculations. Unfortunately, neither the existing version of IEEE 1584 nor the proposed revision includes guidance for dc arc-flash analysis.

NFPA 70E has provided guidance for arc flash hazards in ac systems for a number of years. In the 2012 version, guidance on arc flash hazards in dc systems was added. This addition has caused concern in the stationary battery industry since arc flash PPE in the stationary battery world has been mostly ignored up to this point.

Arc flash is defined in the latest draft of IEEE 1584 [3] as “a hazardous event usually caused by a metallic tool, test probe, under-rated test instrument or loose equipment part contacting energized bare parts and creating a short circuit or ground fault. It is an explosion with a loud noise, bright light, smoke emitted, and parts thrown. A person standing nearby may be injured or killed. The most common injury is severe burns caused by the intense heat which can ignite clothing.”

NFPA 70E Arc Flash Guidelines

Arc flash occurs when there is a short between phases or polarities. The energy created from an incident has the potential to cause severe burns or worse. There are numerous documented cases of injuries and death occurring from arc flash.

The effect of a short in an electrical circuit can range from a small spark to a large explosion. The severity of the event is determined by the power available from the source (voltage and current) and the duration of the event.

The dangers of an arc flash are heat, pressure and noise created by the event. There may also be flying debris such as molten copper. NFPA 70E mainly addresses the heat aspect of the arc flash event. NFPA 70E recommends levels of Personal Protective Equipment (PPE) to prevent second degree burns.

One of the difficulties of quantifying the hazard created by an arc flash is that there are a number of variables that contribute to the total heat and energy exposure of a person working on a system. Some testing of dc arcs has been performed [4], but this has been limited to experimental setups likely designed to sustain an arc, so much more testing is required to fully understand the dc arc flash risk. Existing recommendations are based on conservative “worse case” energy exposure.

NFPA 70E allows a user to determine the required arc flash PPE by calculating the exposure risk or by using tables within the document. The tables cover specific activities with specific parameters. For any activities not listed in the tables or activities outside of the specified parameters, the exposure risk must be calculated and the PPE determined manually.

The dc arc flash tables within NFPA 70E are based on dc research available at the time of writing ([5], [6], [4]). However, the research is limited. IEEE and NFPA are working together on an arc flash research project that is attempting to further characterize the arc flash hazard both for ac and dc systems. Although there are dc tests planned by this group, no testing has been conducted to date.

NFPA 70E characterizes the required PPE by hazard risk category. The hazard risk category is based on the maximum heat and energy potentially delivered to a worker by an arc flash. (See table 1)

NFPA 70E also describes an arc flash boundary. This boundary is a minimum distance from the potential arc where no arc flash PPE is required. Inside of the arc flash boundary, proper PPE must be worn.

The 2012 edition of NFPA 70E includes a new table (130.7(C)(15)(b)) for dc equipment. Part of the table covers voltages over 100 volts and below 250 volts. The other part of the table covers voltages from 250 volts to 600 volts. Although the tables do not cover voltages below 100 volts, it does not indicate there is no arc flash danger below this voltage. In fact, there are potential arc flash hazards even below 50 volts, depending on various factors, including the amount of short circuit current that is available.

The NFPA 70E dc tables are based on a maximum arc duration of two seconds and a working distance of 18”. When working on batteries, unless there is an overcurrent protective device within the string, the arc may continue until something in the circuit melts which may be longer than two seconds. However, if there is an arc flash event it is assumed that the person will vacate the area around the arc within two seconds, either by the initial pressure blast or a reaction to the event. Therefore, two seconds is a reasonable assumption for determining the maximum exposure time if there is not an interrupting device. The 18” working distance is based on a standard reach.

The NFPA 70E tables for dc indicate that for voltages above 100 and arcing current higher than or equal to 1000 amps, the arc flash boundary is at least 36 inches. Anyone within this boundary must wear arc-rated clothing, arc-rated face shield with wrap around protection to protect the entire head (or flash hood), hard hat, safety goggles, hearing protection and leather work shoes (see table 1). To protect against electric shock, the tables require rubber insulating gloves with leather protectors. Also, article 320 of NFPA 2012 requires that acid resistant gloves be used when working on a battery. Essentially, all of this equipment must be used for all battery maintenance with voltages above 100 volts to comply with the standard.

Table 1. Protective Clothing and PPE[1]

Hazard/Risk Category	Protective Clothing and PPE
1	Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 • Arc-rated long-sleeve shirt and pants or arc-rated coverall • Arc-rated face shield with wrap around protection or arc flash suit hood • Hard hat • Safety glasses or goggles • Hearing protection • Heavy duty leather gloves • Leather work shoes
2	Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 • Arc-rated long-sleeve shirt and pants or arc-rated coverall • Arc-rated face shield with arc-rated balaclava or arc flash suit hood • Hard hat • Safety glasses or goggles • Hearing protection • Heavy duty leather gloves • Leather work shoes
3	Arc-Rated Clothing, Minimum Arc Rating of 25 cal/cm^2 • Arc-rated clothing to meet the required arc rating which may include a combination of shirt, pants, coveralls, flash suit jacket and flash suit pants • Arc-rated flash suite hood • Arc-rated gloves • Hard hat • Safety glasses or goggles • Hearing protection • Leather work shoes
4	Arc-Rated Clothing, Minimum Arc Rating of 40 cal/cm^2 • Arc-rated clothing to meet the required arc rating which may include a combination of shirt, pants, coveralls, flash suit jacket and flash suit pants • Arc-rated flash suite hood • Arc-rated gloves • Hard hat • Safety glasses or goggles • Hearing protection • Leather work shoes

DC Arc Flash Calculations

The main concern that NFPA-70E addresses is the heating associated with an arc flash. The basic calculations are as follows:

$$(1) Power = V_{dc} \times I_{dc}$$
$$(2) Power_{arc} = V_{arc} \times I_{arc} = (I_{arc})^2 \times R_{arc}$$
$$(3) E_{arc} = (I_{arc})^2 \times R_{arc} \times t_{arc}$$

Where: $Power_{arc}$ is the power generated by an arc, which is assumed to be constant (watts)
V_{arc} is the voltage across the arc
I_{arc} is the current through the arc
R_{arc} is the resistance of the arc
E_{arc} is the total energy of the arc (joules)
t_{arc} is the duration of the arc (seconds)

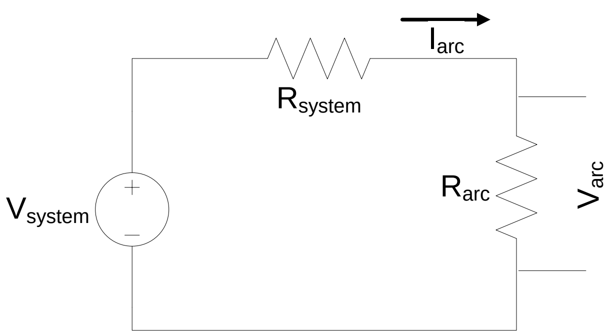

Figure 1. Basic Arcing Circuit

The energy of the arc is dependent on how long the arc is sustained. With ac systems, the time of an arc event is determined by the trip time of the overcurrent protection device (OCPD). Within a battery, this time is indeterminate since there is no interrupting device internal to the battery. The time depends on an interconnection meltdown, material burn back and/or arc self-extinguish. A time of two seconds is recommended if there is not an interrupting device. Within two seconds, the technician is either blown back by the pressure wave or will move out of danger voluntarily.

In an open air situation, the arc is a point source, which emits energy uniformly in all directions. The equation to determine the energy at a distance is as follows:

$$(4)\quad E_s = \frac{E_{arc}}{4\pi d^2}$$

Where: E_s is the energy at any point away from the arc
E_{arc} is the total energy of the arc
d is the distance from the arc

The energy drops off quickly ($1/d^2$) from the point of the arc.

NFPA 70E Annex D provides a method for determining the arcing current given the short circuit current. NFPA 70E also includes a calculation for the arc energy given the system voltage, the arcing current and the time of the arcing.

$$(5)\quad I_{arc} = 0.5\ x\ I_{sc}$$

$$(6)\ E_{arc} = 0.01\ \times I_{arc}\ \times V_{system}\ \times \frac{t_{arc}}{d^2}$$

Where: E_{arc} is the total energy of the arc (cal/cm^2)
I_{arc} is the current through the arc
V_{system} is the system voltage
t_{arc} is the total time of the arc (seconds)
d is the distance from the arc (cm)

Annex D calculations are primarily based on a paper authored by Daniel Doan [6]. Doan based his calculations on the maximum power that can be delivered to an arc which is probably a very conservative estimate. However, if the arc flash occurs in an enclosure, the heat energy will be focused in the cabinet opening which could multiply the effect by a factor of three [7].

Another paper that studied the dc research in a more detailed fashion was written by Ammerman et. al [5]. This paper was also a reference for the basis of the NFPA 70E recommendations.

The Ammerman paper looked at various models for determining the arc resistance and the arc current for dc systems. Their conclusion was “arc-resistance voltage-drop approaches a constant value” for high current systems such as large stationary batteries. The following equations were presented in this paper.

$$(7)\ R_{arc} = \frac{20\ + 0.534\ \times z_g}{I_{arc}^{0.88}}$$

$$(8)\ I_{arc} = \frac{V_{system}}{R_{system}\ + R_{arc}}$$

Where: R_{arc} is the resistance of the arc
z_g is the length of the gap in mm
I_{arc} is the current through the arc
V_{system} is the system voltage
R_{system} is the resistance of the dc system including cables, connectors and cells

Equations (7) and (8) need to be solved simultaneously in order to obtain the arcing current. Once the arcing current and arc resistance is determined, then equation (9) can be used to determine the energy at any point away from the arc.

$$(9)\ E_{arc} = 0.239 \times I_{arc}^2 \times R_{arc} \times \frac{t_{arc}}{4\pi d^2}$$

Where: E_{arc} is the total energy of the arc (cal/cm^2)
I_{arc} is the current through the arc
R_{arc} is the resistance of the arc
t_{arc} is the total time of the arc (seconds)
d is the distance from the arc (cm)

Sample Calculations

Given the known calculation methods mentioned herein, a few sample calculations are shown below.

The first example is a large vented lead-acid UPS battery installation. The relevant information for this battery is shown in Table 2.

Table 2. Sample Battery 1

Battery Type	UPS, high gravity
Number of Plates	35
Short Circuit Current	31,000 amps
Number of Cells	240
Open Circuit Voltage	2.10 volts
Battery Internal Resistance	68 µohms

Assuming the arcing current is 50% of the short circuit current, the dc tables in NFPA 70E cannot be used since the maximum short circuit current is above the highest value stated in the NFPA 70E table. The maximum arcing current listed in the table is 10,000 amps at voltages between 250 and 600 volts dc. The PPE required for arcing currents of 10,000 amps is category 4 with an arc flash boundary of 96" (8 feet). Anyone within 8 feet of the battery would have to have at least category 1 PPE (see Table 1). Personnel working directly on the battery would have to wear category level 4 PPE. However, the battery described in Table 2 is at even a higher risk than the one described in the NFPA 70E tables.

Using equations (5) and (6), the calculated energy at 18" is as follows.

$$I_{arc} = 0.5\ x\ 31{,}000 = 15{,}500\ amps$$
$$E_{arc} = 0.01 \times 15{,}500 \times 240 \times 2.10 \times \frac{2}{(18" \times 2.54)^2} = 75\ cal/cm^2$$

The calculation implies that the heat at 18" will be about twice the maximum value that can be protected by category level 4 PPE. Essentially this means that an arc flash event is not survivable in this situation.

Using equations (7) and (8) from Ammerman [5]:

$$R_{arc} = \frac{20 + 0.534 \times z_g}{I_{arc}^{0.88}}$$

$$I_{arc} = \frac{240 * 2.10}{240 * (68\mu\Omega + 10\mu\Omega) + R_{arc}}$$

Note that 10µΩ was added to the total resistance per cell to account for the intercell connector resistance for each cell. The arc gap was varied between 0.5 and 20 inches and the result is shown in Figure 1 below.

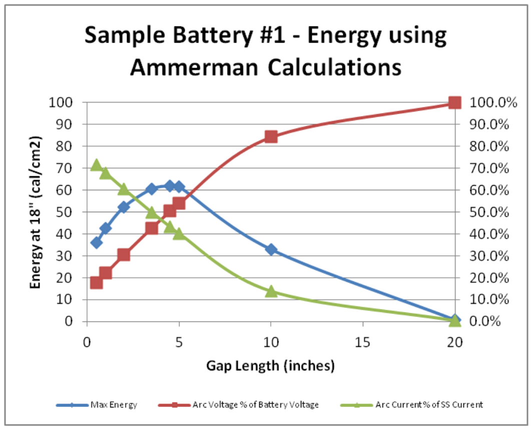

Figure 2. Sample Battery #1 Energy

Figure 2 shows that the peak energy is about 60 cal/cm^2 with an arc voltage of about 50% of the system (battery) voltage and an arc current of about 43% of the short circuit current at a gap length of about 4.5”. This has a reasonable correlation with the NFPA 70E calculations. However, the 60 cal/cm^2 still far exceeds the maximum energy that is survivable with proper PPE.

What is not known is the sustainability of the arc at these gap lengths. At gap lengths approaching 20”, the maximum energy drops below 1.2 cal/cm^2 which is the minimum energy where arc flash PPE is required. However, it is unlikely that an arc would be sustainable for two seconds at gaps above a few inches based on the testing that has been accomplished to date[4]. For example, with an arc gap of 4.5”, the arc may only be sustainable for 200 milliseconds. If that would be the case, the total power would be 1/100th of the 60 cal/cm^2 energy shown in Figure 1. The actual energy would be 0.6 cal/cm^2 which is below the point where arc-flash PPE is required.

The second example is for a multiple cell unit valve-regulated lead-acid UPS battery installation. The relevant information for this battery is shown in Table 3.

Table 3. Sample Battery 2

Battery Type	UPS, VRLA
Battery Rating	~500 watts/cell
Short Circuit Current	4,500 amps
Number of 12 Volt Units	40
Open Circuit Voltage	12.6 volts
Battery Internal Resistance	2.8 mohms

Again, assuming the arcing current is 50% of the short circuit current, the dc tables in NFPA 70E can be used. There is a listing for a battery at 500 volts and an arcing current of 2,250 amps. The NFPA 70E table states that a PPE level 2 is required with an arc flash boundary of 4 feet. Personnel working directly on the battery would have to wear category level 2 PPE.

Using equations (5) and (6), the calculated energy at 18” is as follows.

$$I_{arc} = 0.5\ x\ 4{,}500\ = 2{,}250\ amps$$

$$E_{arc} = 0.01\ \times 2{,}250\ \times 40\ \times 12.6\ \times \frac{2}{(18"\ \times 2.54)^2}\ = 10.8\ cal/cm^2$$

The 10.8 cal/cm^2 requires that category 3 PPE would be required to work within 18 inches of the battery.

The Ammerman calculations were repeated for this example. 50μΩ was added to the total resistance per unit to account for the interunit cable resistance. The arc gap was varied between 0.5 and 20 inches and the result is shown in Figure 2 below.

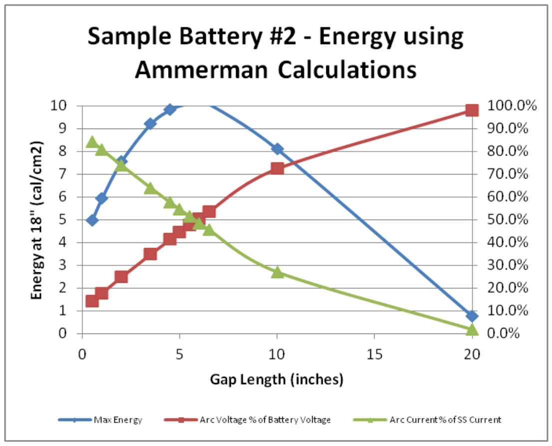

Figure 3. Sample Battery #2 Energy

Figure 3 shows that the peak energy is about 10 cal/cm^2 with an arc voltage about 50% of the system (battery) voltage and an arc current about 50% of the short circuit current at a gap length of about 5”. This result has a reasonable correlation with the NFPA 70E calculations.

The final example is a large vented, long duration telecommunication type lead-acid battery. The relevant information for this battery is shown in Table 4.

Table 4. Sample Battery 3

Battery Type	Long duration, vented
Ahr Rating of Battery	4000
Short Circuit Current	27,300 amps
Number of Cells	5
Open Circuit Voltage	2.05 volts
Battery Internal Resistance	75 µohms

To show the lower limits of arc flash potential, a five cell configuration is used. The NFPA 70E dc tables are only valid down to 100 volts, so a calculation would have to be performed.

Using equations (5) and (6), the calculated energy at 18” is as follows.

$$I_{arc} = 0.5\ x\ 27{,}300\ = 13{,}650\ amps$$

$$E_{arc} = 0.01\ \times 13{,}650\ \times 5\ \times 2.05\ \times \frac{2}{(18"\ \times 2.54)^2} = 1.3\ cal/cm^2$$

The 1.3 cal/cm^2 requires that category 1 PPE would be required to work within 18 inches of the battery. Therefore, even on a very low voltage battery, arc flash potential does exist.

The Ammerman equations do not provide meaningful results at these low voltages.

Calculated Heating Compared to Test Data

While much more testing is needed to quantify the arc flash risk, some dc arc flash testing has been accomplished[4]. This testing utilized a low impedance transformer connected to high power rectifiers. The test setup was capable of producing 25,000 amp arcing faults for up to two seconds. Two test voltages were used: 130 volts and 260 volts. For 130 volts, an arc gap of 0.5” was used. For the 260 volt testing, arc gaps of one and two inches were utilized.

The results of this testing are compared to the Doan and Ammerman calculations in Table 5 and Figures 4, 5 and 6.

Table 3. Test Data vs. Calculated Energy

			Test		Doan		Ammerman	
Voltage	Short Circuit Current	arc gap (inches)	arc current	Energy (cal/cm2) 12", 2 sec	arc current	Energy (cal/cm2) 12", 2 sec	arc current	Energy (cal/cm2) 12", 2 sec
130	4000	0.5	2300	4.2	2000	5.6	1955	5.3
130	20000	0.5	6200	7.5	10000	28.0	7904	25.4
260	2000	1	1000	1	1000	5.6	1385	4.5
260	2000	2	500	1	1000	5.6	1155	5.2
260	4000	1	2500	4	2000	11.2	2669	9.5
260	4000	2	2000	5	2000	11.2	2176	10.6
260	8000	1	4500	8	4000	22.4	5122	19.6
260	12000	1	6500	13.4	6000	33.6	7482	30.0
260	20000	1	10000	22	10000	56.0	12028	51.0
260	22000	2	6500	22	11000	61.6	9962	58.0
260	25000	1	11750	25	12500	70.0	14785	64.3
260	31000	2	9500	36	15500	86.8	13421	81.0

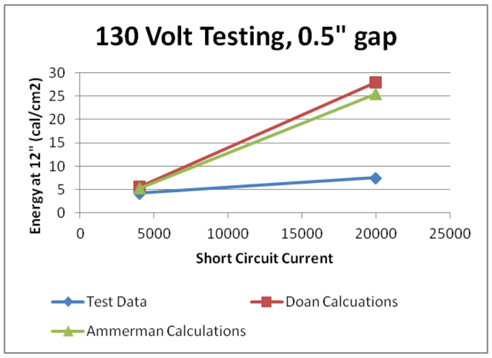

Figure 4. 130 Volt Testing (0.5" gap)

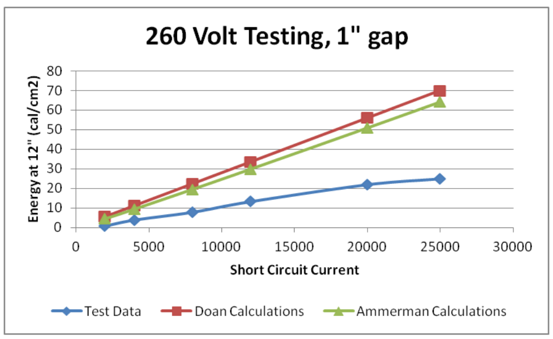

Figure 5. 260 Volt Testing (1" gap)

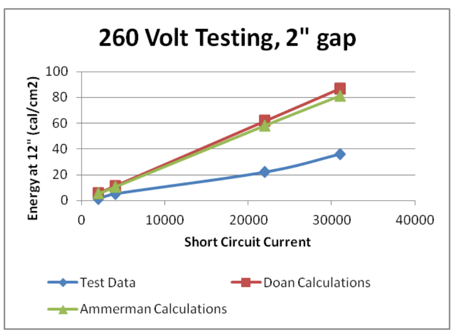

Figure 6. 260 Volt Testing (2" gap)

It is obvious from the above information that the calculations are very conservative as compared to the actual test data. It is also noted that the testing revealed that it was not possible to sustain arcs at 130 volts for gaps above 0.5”. Even at a 0.5” gap, the arcs were only sustainable up to 800 milliseconds.

The calculated values assume the worst case power delivered to the arc. The test data show that the actual power delivered to the load may be substantially less than the worst case. The calculations also assume that all of the energy delivered to the arc will be converted to radiant heat. The reality is that some of the energy is converted to sound and the melting of the metal conductors.

Practical Safety Guidelines for Battery Maintenance

If the guidelines of NFPA 70E are strictly followed, most 120 volt and UPS systems would require significant PPE to perform battery maintenance activities. The fact is that the amount of PPE required may actually reduce safety since personnel may be so restricted (by the PPE) that a hazard could be created. The intention of NFPA 70E is clearly not to create a hazard, it is to protect personnel. Therefore a reasonable approach needs to be developed where precautions are taken to ensure personnel safety while allowing normal battery maintenance to occur.

In the arc flash tables, NFPA 70E 2012 identifies arc flash hazards for dc voltages above 100 volts. However, there may be arc flash potentials at much lower voltages, even voltages below 50 volts as shown in the calculations section. While 50 volts nominal is the cutoff for shock hazard concerns, it is NOT the minimum voltage for arc flash concerns. With large UPS cells, the short circuit can exceed 30,000 amps which can, in theory, create an arc blast causing 2nd degree burns at voltages as low as 10 volts using the NFPA 70E formulas.

Given the sample calculations shown in this paper, there is a significant risk of arc flash around stationary batteries. However, the important question revolves around what is practical. An arc has to be initiated with a short circuit or a ground fault and must be sustainable for up to two seconds to create the energy used in the sample calculations. If the arc is only sustained for 20 milliseconds, the energy will only be 1/100th of the energy shown in the sample calculations.

In the test report[4], air gaps of 0.5 inches at 130 volts DC and 1 and 2 inches at 260 volts were used. No other voltages were tested. At 130 volts, the arc was not sustainable for gaps above 0.5 inches. Even at 260 volts DC, arcs could not be sustained (< 100 milliseconds) for gaps of 0.5 inches if the arcing current was less than 5000 amps.

The test report also revealed that the actual energy may be up to 1/3 of the calculated values.

The most common stationary battery configurations are 24 volt (telecommunications, cellular), 48 volt (telecommunications), 120 volt (switchgear, utility), and 360-480 volt (UPS). The majority of the 120 volt and UPS installation are ungrounded systems. The risk of an arc flash to ground in ungrounded systems is non-existent as long as there is not a ground fault condition.

Most 24 and 48 volt systems are grounded, but the voltage is so low that the risk of arc flash is reduced, but not eliminated.

For battery installations on open racks on ungrounded systems (typical for 120 volt and UPS batteries), the potential for arc flash concerns rest mainly with the main battery terminals. If there are cabinets associated with the battery, such as disconnects and distribution, then there is probably a high arc flash potential in these locations. Extreme precautions are warranted for battery disconnects and dc distribution cabinets when they are energized.

For batteries that are placed in cabinets, especially high voltage applications such as UPS, the risk of shorting is probably substantially higher and therefore the risk of arc flash is greatly increased. An arc flash in a cabinet will concentrate the energy toward the opening which can increase the arc flash energy by a factor of three. Therefore, even though the aforementioned calculations are conservative, they may be accurate for an arc flash within a battery cabinet.

For work around all batteries, the everyday work clothing specified by NFPA 70E (Annex H) is a reasonable recommendation. This recommendation includes arc-rated long-sleeve shirt (minimum arc rating of 8) and arc-rated pants (minimum arc rating of 8).

On 48 volt batteries, the shock hazard is very low. The NEC does not require shock protection for systems under 50 volts nominal. However, there is a potential hazard for arcing at this voltage. Given that most 24 volt and 48 volt systems are grounded, a short to ground can create a significant spark which will melt tools, connectors and bus bars. Because of the low voltage and the fact that the tool or shorting mechanism is quickly moved or destroyed, the timeframe of the event is quite short and usually significantly less than two seconds. The risk is usually the spray of molten metal and contact burns. The best protection from these types of events is good practices including the use of commercially available insulated tools and trained technicians. Practical PPE are safety glasses and fire retardant gloves. Gloves are probably not necessary for most routine battery maintenance activities where the risk of shorting the battery is very low.

For many 120 volt and UPS battery systems, the systems are ungrounded and are monitored by a ground fault detector circuit. The ground fault detector circuit should limit the possible current to ground to less than five milliamps, a value that will ensure personnel safety. As long as there is not a ground fault, the risk of shock to ground is eliminated. The shock risk is only if a person can reach between two points greater than 50 volts. Working around unprotected battery terminals where the voltage exceeds 50 volts does pose a shock hazard and the technician should wear properly rated gloves. For systems where the cells are installed on open racks and the main terminals are far enough apart or protected, electrical rated gloves are typically not needed.

The arc flash hazard on ungrounded, ground fault monitored, 120 volt and UPS battery systems is also low if there are not locations where shorting could easily occur between points of opposite polarities. For most open rack battery installations, the main arc flash hazard is around the main terminals. If the terminals are not protected and they are within close proximity of each other, personnel should be protected from arc flash if they are working with the arc flash boundary of these terminals. The formulas in NFPA 70E can be used to determine the PPE required for these situations.

There is a high risk of shock and arc flash for cabinetized batteries, especially for UPS installations. In many cases, personnel can easily reach across 100 volts or more in these cabinets. Also, there are typically locations within these cabinets where opposite polarities of 100 volts and more are in close proximity of each other and could be shorted with a small tool or an instrument. The arc flash hazard in these cabinets may require substantial PPE that would make it impossible to perform battery maintenance. The solution for these types of installations may be to have a disconnect capability that breaks the battery into sections before any work or maintenance is done on the battery. Alternatively, or in combination with a battery disconnect, a battery monitoring system may be utilized to obtain battery measurements.

Conclusions

The potential for arc flash on stationary batteries is great, even on lower voltage systems. Unconditionally following the guidance in NFPA 70E will most likely result in a situation where the recommend PPE will make it impossible and/or unsafe to perform battery maintenance.

A more practical approach is to determine where the arc flash hazard areas are on a battery and limit the exposure of personnel to these hazard areas. Arc flash events will not occur unless there is a short. If the battery design takes into consideration arc flash and limits the arc flash potential points, battery maintenance can be performed safely without significant PPE.

For UPS batteries installed in cabinets, there may not be a way to safely perform battery maintenance without breaking the battery into sections or just relying on battery monitoring.

For ungrounded batteries installed on open racks, the PPE in many cases can be limited to safety glasses and everyday arc-rated clothing as identified in Annex H of NFPA 70E. The shock hazard is also minimized under these conditions and in many cases electrically rated gloves are also not needed.

Finally, the personnel hazard from electrolyte is typically overstated. Lead-acid battery electrolyte is dilute (<30%) sulfuric acid that will not cause immediate burns or damage when the acid comes in contact with skin. However, it is an issue if it comes in contact with one’s eyes, so safety glasses are always recommended. Face shields, aprons and acid resistant gloves are not necessary for performing normal battery maintenance and should not be required.

More testing for dc arc flash is certainly needed. However, there is an immediate need to provide more specific guidance for personnel who perform battery maintenance.

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