Simplified Arc-Flash Hazard Analysis Using Energy Boundary Curves

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***Abstract*—A simplified analysis technique that allows for the determination of required arc-flash personal protective equipment (PPE) based on IEEE Std. 1584-2002 and overcurrent protective device (OCPD) characteristics is presented. Unlike the simplified equations in IEEE 1584, this analysis technique can potentially be applied to any type of OCPD on any power system within the range of applicability of the IEEE 1584 empirical equations. While the method does not exactly calculate incident energy levels and flash-protection boundaries at the buses under consideration, it does allow for an accurate determination of required PPE levels and maximum flash-protection boundary distances. This level of detail is often all that is required to enable workers to adequately protect themselves against arc-flash hazards. Actual studies performed in industrial facilities have shown that significant reductions in required data collection and analysis times have been achieved using the energy boundary analysis method.**

***Index Terms*—Arc flash, arcing fault current, energy boundary, personal protective equipment (PPE), safe work practices, short-circuit current.**

I. Introduction

RECENT WORK in characterizing the potential arc-flash hazards in electric power systems has led to an increased awareness of the hazards faced by those who work on or near exposed energized equipment. An arc-flash hazard assessment must be performed in order to determine the level of personal protective equipment (PPE) that the one performing such work needs in order to be adequately protected. Performing an arc-flash hazard analysis using the equations and procedures defined in IEEE 1584 satisfies this need. The arc-flash study is often performed in conjunction with short-circuit and device coordination studies of the facility.

Short-circuit and coordination studies in the industrial facilities in the U.S. have typically extended from the service-entrance equipment through the low-voltage (LV) switchgear or motor-control centers (MCCs) in the facility. If the scope of the arc-flash study is the same as for the other studies, many locations where workers may be exposed to hazards will go “unanalyzed”—equipment control panels, disconnect switches, junction boxes, etc. Since an arc-flash analysis requires the determination of short-circuit levels and the evaluation of overcurrent protective device (OCPD) characteristics, the system studies may need to be extended to cover this equipment. This can cause field data-collection requirements and analysis time required for the studies to grow tremendously and can ultimately require several times the effort needed to execute the more traditional study work scope. For this reason, the use of a simplified arc-flash analysis method can be of great benefit when extending arc-flash studies to include most or all distribution equipment in an industrial facility.

II. Constant-Energy Equation

The “incident energy” is defined in IEEE 1584 as “the amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event” [1]. The incident energy at any given point in a power system may be calculated as

$$E = 4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{610^x}{D^x}\right) \text{ (J/cm}^2\text{)} \qquad (1)$$

where C_f is a calculation factor based on system voltage (1.5 for voltages of 1 kV or less; 1.0 for voltages above 1 kV), E_n is the normalized incident energy (J/cm^2), t is the arcing fault duration (in seconds), D is the working distance from the arc source (in millimeters), and x is the distance exponent from Table 4 of IEEE 1584.

For a given type of equipment (e.g., a 480-V MCC or a 208-V panelboard), C_f and x will be constant, as will be the default value for D. The values of E_n and t will vary, depending on the available fault current at the location under consideration and the characteristics of the upstream OCPD.

Equation (1) can be rewritten as

$$t = \frac{E}{A_1 E_n} \text{ (in seconds)} \qquad (2)$$

where A_1 is a constant defined as

$$A_1 = 4.184 \frac{C_f}{0.2}\left(\frac{610^x}{D^x}\right). \qquad (3)$$

IEEE 1584 defines the normalized incident energy as

$$\log E_n = K_1 + K_2 + 1.081 \log I_a + 0.0011 G \qquad (4)$$

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where K_1 is a constant related to equipment configuration (-0.792 for "open-air" configurations; -0.555 for enclosed equipment), K_2 is a constant dependent on system grounding (-0.113 for grounded systems; zero for ungrounded or impedance-grounded systems), I_a is the arcing fault current (in kiloamperes), and G is the bus gap between conductors (in millimeters).

All the terms on the right-hand side of (4) other than I_a are fixed for a given type of equipment. Simplifying (4) and combining with (2) yield

$$t = \frac{E}{A_1 A_2' I_a^{1.081}} \text{ (in seconds)} \tag{5}$$

where A_2 is a constant defined as

$$A_2 = K_1 + K_2 + 0.0011G \tag{6}$$

$$A_2' = 10^{A_2}. \tag{7}$$

Once the constants are defined based on the equipment and system configuration, an incident energy value E can be chosen, and (5) can be used to define a series of time–current points that correspond to the selected incident energy level. As shown in [2], the curve connecting the time–current points corresponding to a given incident energy level appears linear on a log–log graph.

Equation (5) can be applied at locations within the IEEE 1584 range of applicability (208 V–15 kV, three phase, and with available bolted fault current levels of 700 A–106 kA). For locations that fall outside of the range of the empirically derived IEEE 1584 equations, the IEEE 1584 equation based on the Lee method [3] can be used to define the constant-energy curves. Incident energy is defined as

$$E = 2.142 \times 10^6 V I_{\mathrm{bf}} \left(\frac{t}{D^2}\right) \text{ (J/cm}^2\text{)} \tag{8}$$

where V is the system voltage (in kilovolts), I_{bf} is the bolted fault current value (in kiloamperes), t is the arc duration (in seconds), and D is the working distance (in millimeters). Equation (8) can be rearranged to solve for the arc duration and becomes

$$t = \frac{ED^2}{2.142 \times 10^6 V I_{\mathrm{bf}}}. \tag{9}$$

Unlike (5), (9) is based on the bolted fault current, but the arcing fault current value is still required so that the arc duration can be determined. For voltages over 15 kV, IEEE 1584 recommends assuming that the arcing fault current is equal to the bolted fault current. For LV systems, the assumption from [3] that the arcing fault current equals half the available bolted fault current should be used instead.

III. ENERGY BOUNDARY CURVES

National Fire Protection Association (NFPA) 70E-2004 [4] defines five arc-flash PPE categories based on the available incident energy level at a given location. These are summarized in Table I.

TABLE I
SUMMARY OF PROTECTIVE CLOTHING CATEGORIES[A]

Hazard/Risk Category	PPE Minimum Arc Rating (cal/cm^2)	PPE Minimum Arc Rating (J/cm^2)
0	N/A[B]	N/A[B]
1	4	16.74
2	8	33.47
3	25	104.6
4	40	167.36

A – From Table 130.7(C)(11) of NFPA 70E-2004 [4]
B – Category 0 clothing is allowed for incident-energy exposures of up to 8.36 J/cm^2 (2.0 cal/cm^2)

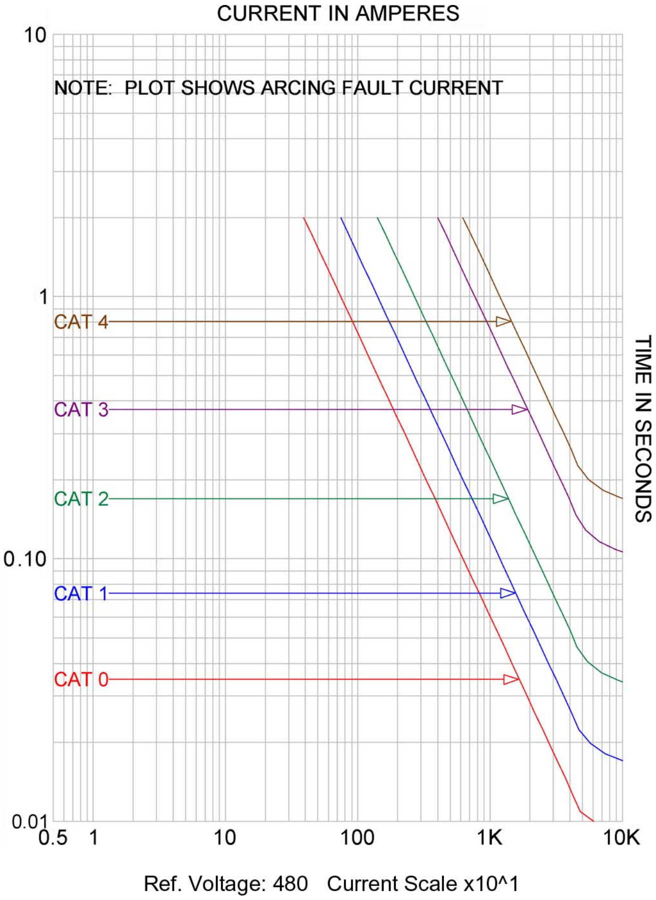

Fig. 1. Energy boundary curves for 480-V solidly grounded panel/MCC.

By setting E in (5) or (9) equal to one of the minimum arc rating values shown in Table I, a constant-energy curve can be defined, which corresponds to the maximum incident energy level allowed for that PPE category. For example, for PPE category 0 ($E = 8.36$ J/cm^2) and analysis at an MCC on a 480-V solidly grounded system, (5) becomes

$$t = 0.7254 I_a^{-1.081} \text{ (in seconds)}. \tag{10}$$

The time–current relationships can be calculated for each PPE category to define a set of constant-energy curves. The curves corresponding to each PPE category for this example are shown in Fig. 1. Note that these curves are cut off at a maximum time of 2 s. Clause B.1.2 of the IEEE 1584 states that, in many situations, 2 s is a "reasonable" maximum fault duration for use in calculations. The constant-energy curves can be extended beyond this point if necessary. The curves are also cut off at 100-kA arcing fault current. The IEEE 1584 empirical equations are applicable up to 106-kA bolted fault current. For a solidly grounded 480-V panel, this yields an arcing fault current of 49.3 kA. Above this level, (9) was used to extend the curves. In this case, the Lee method produces a less conservative result than the IEEE 1584 empirical equations; thus, the curves shown in Fig. 1 are interpolated between 49.3 kA and the time–current point calculated using (9) at 100-kA arcing fault current. A similar transition point between the IEEE 1584 empirical method and the Lee method may be calculated for each type and voltage class of equipment.

The leftmost curve in Fig. 1 ("CAT 0") corresponds to an incident energy level of 8.36 J/cm^2. For time–current points that fall below or to the left of this curve, the available incident energy will be less than 8.36 J/cm^2. For points above or to the right of this curve, the available incident energy will be greater than 8.36 J/cm^2. Since this incident energy value marks the transition from Category 0 to Category 1 PPE, the "CAT 0" curve defines the boundary in Fig. 1 between time–current points, where Category 0 PPE is adequate and those where it is not. Since the other curves are calculated based on maximum incident energy levels for the other PPE categories, the "CAT 1"–"CAT 4" curves define the upper limits on the time–current plot for each of the other PPE regions. These particular constant-energy curves are denoted as the "energy boundary" curves. While Fig. 1 shows only the energy boundary curves for a solidly grounded 480-V MCC or panel, a set of energy boundary curves can be generated for any type or class of equipment—480-V switchgear, medium-voltage equipment, etc.

IV. APPLICATION TO ARC-FLASH ANALYSIS

The energy boundary curves may be used as the basis of a simplified arc-flash analysis method that is particularly useful when applied in systems where many circuits are fed from a common bus. Examples of this include facilities where plug-in busway feeds many panels, control panels, or other equipment on a factory floor or in facilities where LV MCCs containing many branch devices feed similar load equipment. The energy boundary curves allow for a quick determination of the required PPE level—although not the exact incident energy level—at such locations. In this section, three examples will be given to illustrate the application of the energy boundary curves in arc-flash analysis.

A. 125-A Fused Disconnect

Consider Fig. 2, which shows the time–current characteristics of a 125-A class RK-5 LV fuse and the Category 0 PPE energy boundary curve for a 480-V solidly grounded MCC. Three time–current points—P1, P2, and P3—are shown on the plot. P1 is the point where the fuse total clearing curve intersects 2 s, at an arcing fault current of approximately 1046 A. P2 is where the Category 0 energy boundary and total clearing curves of the fuse intersect, at 1422 A and 0.5 s. P3 is the point where the total clearing curve of the fuse intersects 0.3 s on the time axis, corresponding to 1623-A arcing fault current. The incident energy level at each point, calculated using the IEEE 1584 empirical equations, is shown in Table II.

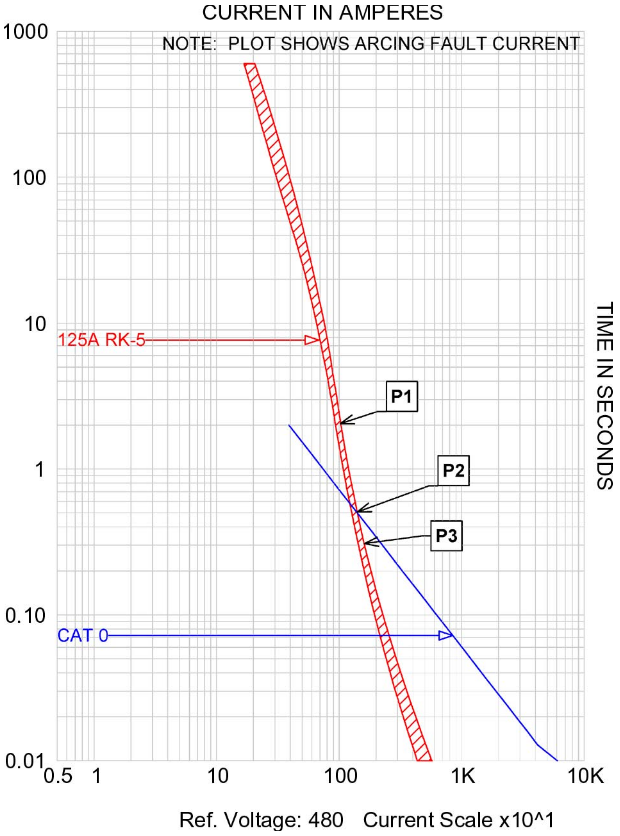

Fig. 2. Selected points on the 125-A RK-5 fuse curve.

TABLE II
INCIDENT ENERGY VALUES AT SELECTED POINTS IN FIG. 2

Point	Arcing FC (kA)	Arc Duration (Sec.)	Incident Energy (J/cm^2)
P1	1.05	2.00	24.2
P2	1.42	0.50	8.36
P3	1.62	0.30	5.87

As seen in Fig. 2, point P1 falls above the CAT 0 energy boundary curve. Table II shows that the calculated incident energy level at P1 is higher than the Category 0 limit. P3 falls below the energy boundary curve; thus, the incident energy level is less than the Category 0 limit, and Category 0 PPE is adequate for this location. At P2, which is a point on the energy boundary curve, the incident energy is exactly equal to the upper limit for Category 0 PPE.

P2—the intersection of the selected energy boundary curve and OCPD characteristic curve—is the key to the simplified analysis method. Since the slope of the fuse curve is steeper than that of the energy boundary curve, the incident energy at the downstream bus drops as the available arcing fault current increases. For all arcing fault currents above this intersection value, which is the *minimum arcing fault current* (I_{am}) value, the PPE corresponding to the selected energy boundary curve will be adequate, while arcing fault currents falling below I_{am} will require a higher category of PPE.

To extend this example, suppose that several 125-A RK-5 fuses are applied in several busway plug-in disconnects that, in turn, each feed a 125-A panelboard. What PPE category is required at each panel?

The minimum arcing fault current corresponding to Category 0 PPE for this particular case is 1422 A; thus, as long as the arcing fault current level at the panels exceeds 1422 A, then Category 0 PPE will be adequate at each location. The IEEE 1584 empirical model calls for the calculation of two incident energy values for each bus in LV systems—one using 100% of the calculated arcing fault current and a second using 85% of the calculated value. The higher of the incident energy values is then reported as the single incident energy level for that bus. Since the incident energy increases as the available fault current decreases at equipment protected by a fuse, the worst case incident energy value will be the one calculated using the 85% arcing fault current. In this case, the 1422 A is taken to be the "85% value" for the arcing fault current at the panels. The "100% value," which corresponds to the *target arcing fault current* (I_{at}; 1673 A in this example), is the level of arcing fault current that must be present at each panel (per the IEEE 1584 equation for arcing fault current) in order for Category 0 PPE to be adequate. For LV systems, this 85%/100% relationship between the *minimum* and *target* arcing fault current levels will often hold true.

The arcing fault current is calculated in the IEEE 1584 empirical model as

$$\log I_a = K + 0.662\log I_{\mathrm{bf}} + 0.0966\,V + 0.000526\,G + 0.5588\,V(\log I_{\mathrm{bf}}) - 0.00304\,G(\log I_{\mathrm{bf}}) \quad (11)$$

where I_a is the arcing fault current (in kiloamperes), K is a constant related to equipment configuration (−0.153 for "open" configurations and −0.097 for "box" configurations), I_{bf} is the three-phase symmetrical rms bolted fault current (in kiloamperes), V is the system voltage (in kilovolts), and G is the "bus gap" between conductors (in millimeters).

Collecting terms in (11) and solving for the arcing fault current I_a yield

$$I_a = A_4' I_{\mathrm{bf}}^{A_3}\ (\mathrm{kA}) \quad (12)$$

where A_3 and A_4 are constants defined as

$$A_3 = 0.662 + 0.5588\,V - 0.00304\,G \quad (13)$$

$$A_4 = K + 0.0966\,V + 0.000526\,G \quad (14)$$

$$A_4' = 10^{A_4}. \quad (15)$$

Solving (12) for the bolted fault current I_{bf} yields

$$I_{\mathrm{bf}} = \left(\frac{I_a}{A_4'}\right)^{-A_3}\ (\mathrm{kA}). \quad (16)$$

Equation (16) can be used to determine a *target bolted fault current* (I_{bt}) value, which is the minimum bolted fault current level at the local bus (the one being analyzed) required to produce an arcing fault current equal to I_{at}. The relationship between I_{at} and I_{bt} varies, depending on the type of equipment under consideration and the system grounding. Applying (16) to a 480-V panelboard with a standard bus gap (25 mm) in a solidly grounded system gives

$$I_{\mathrm{bt}} = (1.0902 I_{\mathrm{at}})^{1.1707}\ (\mathrm{kA}). \quad (17)$$

An I_{at} of 1673 A gives a value of approximately 2.02 kA for I_{bt}. Therefore, as long as the available bolted fault current at the panelboards is greater than 2.02 kA, Category 0 PPE will be adequate. If a detailed fault current information is available at each panel, then the analysis may be straightforward but not necessarily much more efficient than using a computer analysis package to calculate arc-flash levels at each panel. However, if short-circuit calculations have *not* been performed to this level in the system, the analysis using the energy boundary curves can reduce the required data collection and analysis times required to determine the appropriate PPE category at the downstream panels.

Assume that the feeder to each panelboard consists of one #1 American wire gauge (AWG) copper conductor per phase in steel conduit. The impedance of the conductor is 0.170 Ω per 1000 ft (305 m) at 75 °C [5]. The available three-phase bolted fault current at the busway feeding the panels is 10 kA. As long as the length of the feeder conductor to any panel does not exceed approximately 790 ft (241 m), the three-phase bolted fault current level at the panels will be 2.02 kA or higher. For feeders shorter than this maximum distance, the three-phase bolted fault currents exceed I_{bt}, and the fuse will clear the arcing fault at a point below/left of the Category 0 energy boundary curve (e.g., P3 in Fig. 2). This demonstrates that the Category 0 PPE is adequate. Since such long feeder conductors are not common for small circuits in industrial facilities, it may now be possible to say that Category 0 PPE is appropriate for all 125-A panels fed from this busway even without knowing the exact length of each feeder or performing a detailed analysis at each panel.

This analysis is sensitive to the minimum arcing fault current I_{am}, the bolted fault current at the busway (the *remote bus bolted fault current* I_{rb}), and the impedance of the feeder conductor. When extending the analysis beyond a single remote bus (e.g., in a facility which has several feeder bus ducts serving 125-A panels), the worst case fault current and conductor impedance values may be used to further simplify the analysis. Suppose that the facility under study also has a second bus duct with a minimum I_{rb} value of 5 kA and that some of the 125-A panels fed from this busway are fed by #2 AWG copper conductor, the smallest allowable for this feeder conductor per National Electrical Code Article 240 [6]. Based on the #2 AWG conductor and the 5-kA value for I_{rb}, the maximum feeder length drops from the previously reported 790 to 478 ft (146 m). If no feeder is longer than this maximum length, then this shows that Category 0 PPE is adequate for all 125-A panels fed from busway in the facility. This type of analysis can also be extended to cover other size fuses or circuit breakers.

B. Small OCPDs

Fig. 3 shows the time–current curve for a 30-A 480-V circuit breaker and the Category 0 PPE energy boundary curve for a solidly grounded panel/MCC. Since the energy boundary curve is cut off at 2 s, the OCPD time–current and energy boundary curves never intersect. This indicates that a worker would have to be exposed to the arcing fault for longer than 2 s in order to be exposed to a total incident energy level of 8.36 J/cm^2. If 2 s is an appropriate maximum arcing time, then Category 0 PPE is adequate at any equipment fed from this breaker, regardless

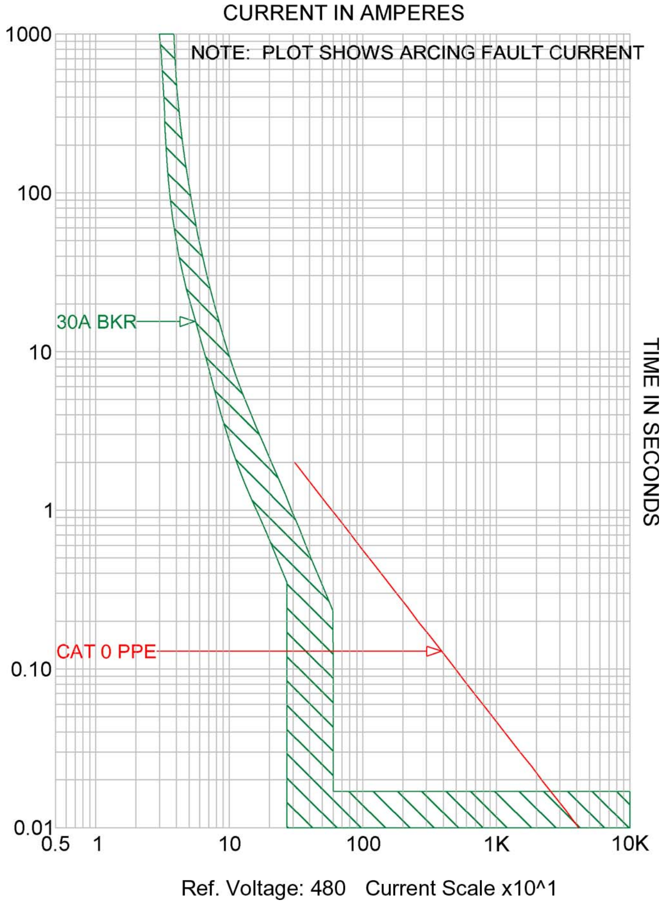

Fig. 3. 30-A breaker curve and CAT 0 PPE curve.

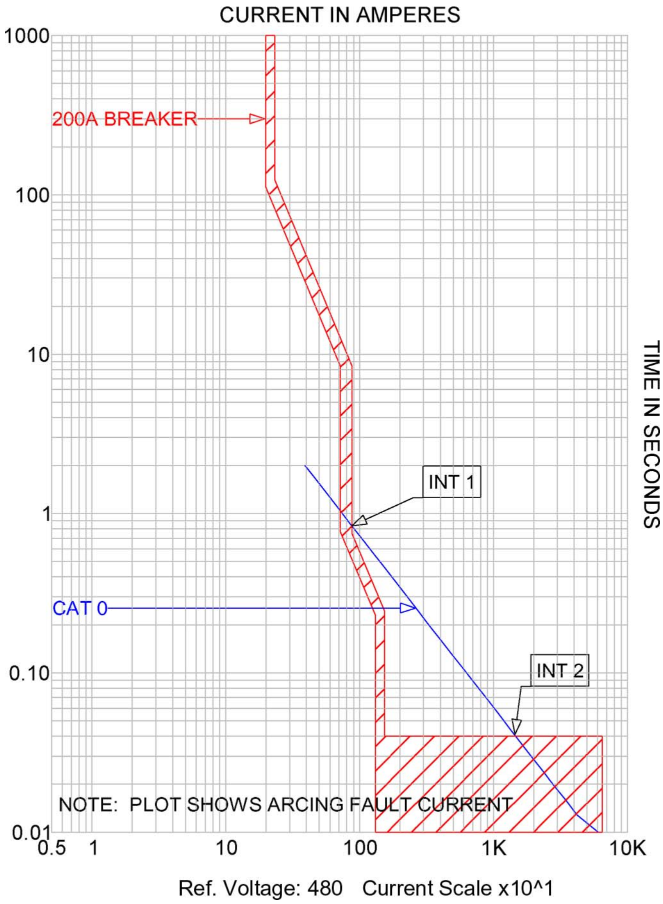

Fig. 4. 200-A breaker trip curve and CAT 0 PPE curve.

of the available bolted fault current at the remote bus or the size and length of the associated feeder or branch circuit conductor. Similarly, the energy boundary curves may not intersect fuse total clearing curves below a certain ampere rating.

C. Larger Circuit Breaker

For larger circuit breakers, the energy boundary curves will intersect the breaker's time–current trip curve. If the available fault current is high enough, the energy boundary curves may intersect the breaker's time–current curve more than once, as shown in Fig. 4. The first intersection point, "INT1" in Fig. 4, corresponds to the minimum arcing fault current I_{am}, as discussed in Section IV-A. The second intersection point "INT2" indicates that, for very high arcing fault current levels, the instantaneous tripping of the breaker is not sufficient to limit the downstream arc-flash incident energy below the Category 0 PPE maximum of 8.36 J/cm^2. For an adjustable-trip breaker, the lower intersecting value (INT1) varies, depending on the trip settings of the breaker; thus, these must be considered when employing the energy boundary method with such a device. Otherwise, the analysis procedure is the same once the minimum arcing fault current value has been established. For the upper intersecting value (INT2), the intersection represents a *maximum* arcing fault current value $I_{a.\max}$. This value, along with the available bolted fault current at the remote bus and the conductor impedance per unit length, can be used to determine a *minimum* allowable circuit length that will allow for a given PPE class at downstream equipment. Since the circuit breaker has a definite-time characteristic above its instantaneous pickup level, the incident energy value calculated for high-level faults based on the 85% arcing fault current will be less than that calculated based on 100% arcing fault current. Therefore, for the upper intersection point, the maximum arcing fault current $I_{a.\max}$ is equal to the maximum target arcing fault current $I_{\mathrm{at.\,max}}$.

If the energy boundary and circuit breaker trip curves do intersect twice, the circuit under consideration will have both minimum and maximum distances that are allowable for the given PPE category. For some devices—such as breakers that will trip within one 60-Hz cycle—the fault current levels required to reach the upper intersection point are very high (e.g., $\geq$ 80-kA bolted fault current at the remote bus); thus, the minimum circuit length may only need to be considered in special circumstances. For current-limiting molded-case breakers, where the trip time drops to 0.01 s or less relatively quickly, the minimum length may not need to be considered at all.

D. Calculating the Flash-Protection Boundary

The flash-protection boundary is defined in NFPA 70E-2004 as "an approach limit . . . within which a person could receive a second degree burn if an electrical arc flash was to occur" [4]. The IEEE 1584 provides an equation for the calculation of the flash-protection boundary distance for the empirically derived model that is based primarily on the normalized incident energy level and the duration of the arcing fault. When an energy boundary analysis is performed, the maximum incident energy level at each bus is established, but exact values for the normalized incident energy and fault clearing time are not determined. However, the IEEE model can still be used to calculate a maximum flash-protection boundary distance corresponding to each PPE class. Since the exact arc-flash levels are not calculated with this procedure, choosing the flash-protection boundary distance based on the maximum incident energy level for each PPE category ensures a conservative result.

From (1), the incident energy level (E_{WD}) at the working distance (D_{WD}) is calculated as

$$E_{\mathrm{WD}} = 4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{610^x}{D_{\mathrm{WD}}^x}\right) \tag{18}$$

while the incident energy level (E_B) at the flash-protection boundary distance (D_B) is equal to

$$E_B = 4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{610^x}{D_B^x}\right). \tag{19}$$

For a given arcing fault event, all quantities in (18) and (19) are equal except for those that vary with distance—E_B, E_{WD}, D_B, and D_{WD}. Dividing (19) by (18) and simplifying yield

$$\frac{E_B}{E_{\mathrm{WD}}} = \left(\frac{D_B}{D_{\mathrm{WD}}}\right)^{-x} \tag{20}$$

where x is the distance exponent from IEEE 1584. Equation (20) gives a maximum flash-protection boundary distance of 624 mm (25 in) for Category 0 PPE (maximum of 8.36 J/cm^2) and a 480-V panel/MCC.

V. CASE STUDY—APPLYING THE ENERGY BOUNDARY METHOD

As part of a short-circuit, coordination, and arc-flash study conducted at an industrial facility, PPE requirements were to be determined downstream of all 480-V MCCs in the facility. Fifty MCCs, each containing an average of 20 fused branch circuits, were present. The MCCs feed numerous equipment and process control panels, disconnect switches, etc., where workers are sometimes exposed to energized equipment. To perform exact calculations at each piece of downstream equipment, the data on protective device types and sizes in each MCC bucket, as well as on conductor size and length for each circuit, would need to be collected. In addition, the extra 1000 buses would need to be modeled and evaluated with the analysis software program. Initial estimates on the data-collection effort alone were in the 250 man–hour range.

Instead, the energy boundary method was applied for the evaluation of PPE requirements downstream of the MCCs. The study was performed in two stages—first, data were collected down to the MCC level, and short-circuit levels were calculated to that point. In addition, full data on MCC branch OCPDs and conductor sizes were collected from a few representative MCCs in the facility. Based on the calculated short-circuit results and preliminary MCC data, the energy boundary method was used to determine that Category 0 PPE was adequate for all equipment directly fed from the MCCs as long as circuit lengths were less than approximately 400 ft (122 m) and OCPD sizes were less than 150–175 A. (The required PPE at the MCCs themselves was most often higher than Category 0). During the second on-site visit, data-collection efforts focused on equipment fed from the MCCs via long circuits and/or large OCPDs, as the preliminary analysis identified these locations as the potential "trouble spots." The total data-collection time at or beyond the MCCs was reduced from an estimated 250 to 12 h, which is a reduction of approximately 95%.

In this case, the simplified analysis technique allowed for the extension of the arc-flash analysis to include virtually every piece of equipment in the facility with minimal added cost and effort. The energy boundary method has also been applied at other sites, including light industrial facilities, automotive plants, and hospitals, with similar results.

VI. CONCLUSION

In Section II, equations based on the IEEE 1584-2002 empirical model were derived to define constant arc-flash incident energy lines that appear linear on a log–log plot. When these constant-energy lines are selected to correspond to maximum arc-flash levels for various categories of PPE, then the lines define boundaries between regions on a time–current plot, which correspond to the PPE categories. These energy boundary curves can be used as a basis for a systematic simplified method for arc-flash hazard analysis.

The energy boundary method applies these boundary curves and allows for efficient determination of required PPE levels and flash-protection boundary distances, particularly when analyzing numerous buses fed from a common point, such as an MCC or plug-in busway. The energy boundary curves and the associated analysis method are based on the equations presented in the IEEE 1584-2002, not on "rules-of-thumb" or "trial and error" analysis. While the examples presented deal with the application of the energy boundary method to 480-V fuses and circuit breakers, the equations can be applied to any type of OCPD on any power system that falls within the range of applicability of the IEEE 1584-2002.

Energy boundary analysis has proven to be a useful tool for efficiently extending the scope of arc-flash studies. Other potential applications for the energy boundary method include the following.

1) As an aid in device coordination, similar to that shown in [2]. The energy boundary curves can be used to help determine breaker or relay settings that will help to minimize arc-flash levels downstream.
2) As a guide for field data-collection efforts for an arc-flash analysis. A preliminary energy boundary analysis can identify buses where the required PPE levels will be low, thereby allowing the data-collection efforts to focus in on areas which have potentially higher energy levels.
3) As a means to perform a quick PPE assessment for field work in an unknown facility. Using the energy boundary method, it may be possible to determine the required PPE levels based upon minimal information, which can

be useful when performing a hazard/risk assessment in a facility where a full arc-flash analysis has not yet been performed.

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