Electrical Safety Community of Practice

ELECTRICAL SAFETY POSITION/GUIDANCE PAPER 2024-02

2-Second Maximum Clearing Time “Use of 2-Second Rule”

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Introduction:

This guidance represents the consensus understanding of the Electrical Safety Community of Practice of the EFCOG Environmental, Safety and Health Working Group for the use of the 2-second rule during arc flash analysis.

Discussion:

There is no established EFCOG or DOE justification for the use of two seconds for a reasonable maximum time for AC and DC incident energy calculations or for a person to either escape from an arc flash incident or be moved out of the arc flash boundary by the arc blast pressure.

EFCOG Position:

Battery systems are often not designed with overcurrent protection devices to clear a fault, and some AC system overcurrent protection devices cannot be relied upon to clear a fault due to condition of maintenance or inability to coordinate protective device settings to quickly trip at the available fault current. NFPA 70E 2024, NFPA 70 2023 and IEEE 1584-2018 provide information to the electrical authority having jurisdiction (AHJ) and other personnel assigned the responsibility of performing arc flash analysis for risk assessment consideration prior to allowing work on exposed electrical equipment, to determine the PPE, adequate working space, and guidance for performing arc-flash calculations, including the device trip time, for calculating incident energy.

Technical basis for the using two seconds as reasonable maximum clearing time:

NFPA 70E 2024
D.2.4 (2) – Calculation of Incident Energy Exposure Greater Than 600 V for an Arc Flash Hazard Analysis.
(2) The total protective device clearing time (upstream of the prospective arc location) at the maximum short-circuit current. If the total protective device clearing time is longer than 2 seconds, consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible, and 2 seconds is a reasonable maximum time for calculations. A person in a bucket truck or a person who has crawled into equipment will need more time to move away. Sound engineering judgment must be used in applying the 2-second maximum clearing time, since there could be circumstances where an employee’s egress is inhibited.

NFPA 70 2023
Article- 110.26(C) Entrance to Egress from Working Space.
(1) Minimum Requirement. At least one entrance of sufficient area shall be provided to give access to and egress from working space about electrical equipment.
NFPA 70 Note: The requirements in this section provide access to and egress from electrical equipment. However, the primary intent is to provide egress from the area so that workers can escape if an arc-flash incident occurs.

IEEE 1584
Section-6.9.1 IEEE Std. 1584-2018 Guide for Performing Arc-Flash Hazard Calculations

If the total protective device clearing time is longer than two seconds (2 s); consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible, and 2 s usually is a reasonable assumption for the arc duration to determine the incident energy. However, this also depends on the specific task. A worker in a bucket truck, or inside an equipment enclosure, could need more time to move away. Use engineering judgement when applying any maximum arc duration time for incident energy exposure calculations, because there may be circumstances where a person's egress may be blocked.

Background:

NFPA 70E 2015 is the current required and accepted standard by DOE and was codified with the publishing of 10 CFR 851. In this and subsequent NFPA 70E versions, it is clearly established that working on or near energized circuits under any circumstances increases the risk to the worker. The fundamental acceptance criteria are provided in the NFPA 70E to significantly reduce but not eliminate this risk. These fundamental acceptance criteria include safety by design, safe work practices, training and qualification, and arc flash and shock risk assessments.

Once the fundamental acceptance criteria for working around energized circuits are met, the NFPA provides information for determining acceptable levels of PPE. These acceptable levels are designed to protect the worker from second-degree burns (1.2 calorie/cm^2), not to ensure absolute prevention of any injury.

The use of 2 seconds is a reasonable maximum time for calculations of AC and DC arc flash incident energy as quoted from the IEEE Guide for Performing Arc-Flash Hazard Calculations, IEEE-1584-2018.

"If the total protective device clearing time is longer than two seconds (2 s); consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible, and 2 s usually is a reasonable assumption

for the arc duration to determine the incident energy."

As determined from discussions with members of the NFPA 70E and IEEE 1584 committees, including nationally recognized experts in arc flash, the following is determined:

The use of 2 seconds as a conservative default value is based on human factors, not electrical circuit parameters, or electrical failure mechanics. Specifically, 2 seconds is based on human reaction times and the ability to remove themselves from the immediate area. This use of two seconds as a reasonable maximum time for calculations of AC and DC incident energy is regularly a source of significant discussion and contention within the electrical community, including the NFPA 70E committee. However, the use of 2 seconds as a conservative value when an egress path is provided continues to pass the NFPA committee as a consensus acceptable approach.

While generally conservative, the use of 2 seconds may increase the risk to the workers. Under both AC and DC conditions, there may be times when the arc flash lasts longer than 2 seconds. This is particularly true under DC current conditions, where many battery systems are not configured or designed to limit or automatically interrupt continued current flow in under 2 seconds. EFCOG acknowledges this risk and site AHJ accepts this risk because this is considered the best generally available information within the electrical community and is considered conservative under most conditions based on workers removing themselves from the area and not interruption of the current.

Another element of this risk is that the fundamental equations used are based upon power output, and do not factor such elements as intense thermal radiation, damaging noise levels, and explosive expansion of surrounding air. These additional risks are more fully described in the IEEE paper, "Protective Clothing Guideline for Electric Arc Exposure" by Thomas Neal Allen Bingham and Richard Doughty published in 1997. Briefly, it is known that all the energy produced by an arc fault is distributed into several forms, i.e., heat, other EM radiation (visible light, UV), phase change of solid material, blast/pressure wave. Assuming, as the Maximum Power Method does, that all the energy available goes into heat results in conservatively high incident energy. If some of the energy produced could be correctly accounted for in these other forms, the heat energy would be demonstrated to be less than calculated.

As a side note, these other energy forms are qualitatively accounted for, by equipping workers with arc rated face shields for the EM radiation hazard, ear plugs for the impulse noise hazard to eardrums, clothing which will not ignite when exposed to thermal energy or molten metal droplets, and by limiting exposure to incident energies.

The EFCOG Electrical Safety Community of Practice agrees as a consensus and accepts that the use of the fundamental equations, and subsequently published charts, do represent an acceptable approach that allows work to be performed in a manner that minimizes but does not eliminate the risk.

When writing the NFPA 70E standards, the NFPA committee members, many of whom come from the DOE community, understand that the guidance provided must be able to be implemented by personnel qualified as Electrical AHJs covering a broad spectrum of capabilities. As a result, the standard is written at a level that reduces the need for highly specialized personnel to make most decisions. In discussions with NFPA committee members, the intent of NFPA 70E as a consensus is that competent Electrical AHJs generally can determine when the 2 second maximum clearing time is appropriate. Times when the maximum clearing time is not appropriate include clear cases of obstruction, including working in a man-lift. It is not the intent of the NFPA 70E committee to require human factors experts or plasma experts to determine each applicable condition as DOE contractors employed and qualified under the AHJ qualification standard or accepted as AHJ by letter on file, one of AHJ responsibilities is to make these decisions.

Statement of Position/Interpretation:

If the arcing time, t, is longer than 2 seconds, consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible, and 2 seconds is a reasonable maximum time for calculations See *Appendix A*. Sound engineering judgment should be used in applying the 2-second maximum clearing time, because there could be circumstances where an employee's egress is inhibited. For example, a person in a bucket truck, in a vault, or a person who has crawled into equipment will need more time to move away.

2 seconds is a reasonable maximum time for AC and DC Arc Flash calculations. This reasonable maximum time is acceptable to NFPA 70E, IEEE, EFCOG and the site E- AHJ. This time is based on personnel leaving the arc flash boundary and is independent of the fault clearing time of the circuits, characteristic of the arc and whether the system is AC or DC.

The AHJ is responsible for minimizing exposure to electrical hazards. The AHJ and those assigned to perform arc flash analysis have many tools available to accomplish this responsibility including the use of codes and standards, lessons learned, experience, industry experts and peers, and the implementation of Safety-By-Design concepts. These tools allow the AHJ and those assigned to perform arc flash analysis to develop and implement sound engineering judgment when performing arc flash analysis, including the appropriate use of the two second maximum clearing time.

Appendix A:

This discussion expands on the concept of a person's reaction time during an incident. A person's reaction time is a composite of many factors. This discussion also demonstrates the basic principles and thought processes involved when using exposure time as a basis for calculating incident energy.

Reaction Time

Reaction time is complicated. Often, reaction times are used without a good understanding of where the numbers came from, how they were acquired, or the variables that shaped them. A reaction time of 1.5 seconds is commonly quoted by experts regarding automobile accidents. In regard to arc flash incidents, 2 seconds is a reasonable maximum time to use when calculating the arc flash incident energy, provided the employee's egress is not inhibited. If the total clearing time of the upstream overcurrent protective device is greater than 2 seconds or if egress is restricted, then additional time might be needed to exit the arc flash boundary.

Engineering judgment must be used to determine if the 2-second exposure time is applicable. Reaction time can be broken down into different components or categories — such as perception, decision, and motor response times — each having dissimilar properties.

Mental Processing Time

Mental processing time is the length of time it takes an employee to recognize that an event has happened (perception time) and to decide upon a response (decision time). For example, it might be the time it takes an employee to realize that an arc flash event is underway and decide what action to take. Perception and decision time can be further broken down into subcategories to better understand the hazard response.

- Perception time.
  Perception time can be broken down into the following two sub-categories:

- Sensation time.
  The time it takes to detect the sensory input of an event is the sensation time. The greater the signal intensity, the better the visibility and the faster the reaction time. Because reaction times can be faster for acoustic signals than for visual signals, the sound wave associated with an arc blast might lead to a faster response time.

- Recognition time.
  The time it takes to understand the meaning of an event is the recognition time. In some cases, an extremely fast automatic response could kick in, while in others, a controlled response, which can take substantial time, might occur. Training can help to decrease the time it takes to respond.

- Decision time.
  Decision time can be broken down into the following two sub-categories:

- Situational awareness time.
  The time it takes to recognize and interpret an event, extract its meaning, and possibly extrapolate it into the future is the situational awareness time. Again, practice or training can decrease the response time.

- Response selection time.
  The time needed to determine what reaction to have and decide what to do is the response selection time. Generally, the response selection time slows when more than one event is perceived or when more than one response is possible (that is, when choice is involved). As with the other categories here, practice or training can decrease the response time.

Additional factors.

The following factors might also have an impact on the response time to an event:

- Movement time.
  Several factors can affect the movement time, such as the number of exit passageways, the length of the passageways, and any obstacles that might be in the way. Generally, the greater the complexity of a movement, the longer it takes. Practice or training can lower movement times. In addition, an emotional stimulus can accelerate gross motor movements but inhibit fine detail movement.

- Expectation.
  It might be possible to get the reaction time down to around 1.4 seconds when the movement time is around 0.7 seconds if an event is expected, practiced for, and rehearsed. The reaction time for an unexpected event could be around 1.75 seconds, including 0.7 seconds of travel time. Extra time might be necessary to interpret an event and decide on the appropriate response when it is a complete surprise. In this case, the best estimate might be around 2.0 seconds, including 1.2 seconds for perception and decision and 0.8 seconds for movement. It might be necessary to study the situation to determine the appropriate reaction time.

Other factors.

Factors such as the perceived urgency, the complexity of a task, whether an employee is holding tools, the employee's mobility and health can affect the overall response time. The more complex an employee’s task when an event happens, the longer the anticipated response time.

- Minimizing Exposure

  The overcurrent protective device’s operating time depends on whether the device is current limiting or not. Depending on the available fault current, an overcurrent protective device might be expected to extinguish an arcing current in anywhere from a ¼ cycle to 30 cycles. Employees cannot outrun arc flash events or minimize their exposure time for such short intervals, but they might be able to minimize their time inside the arc flash boundary when extended tripping times are involved.

  Where the tripping time of the overcurrent protective device is longer than the reaction time of the employee, the employee might be able to increase his or her distance from the arcing event or exit the arc flash boundary. Doubling the distance between the source of an arc flash event and the employee decreases the incident energy level by around four (it is an inverse square relationship). The increase in distance from a perspective arc source should be addressed during the planning process and incorporated into the risk assessment to reduce the incident energy exposure.

  If the overcurrent protective device takes longer than 2 seconds to trip in response to an arcing current, consideration should be given to how long a person is likely to remain within the arc flash boundary. The physical layout needs to be considered when the exposure time is used to calculate the incident energy level. The anticipated exposure time might have to be increased if a narrow aisle is the only means of egress. Other factors to consider include whether it is possible for an employee to get stuck in a position and not be able to escape within the anticipated exposure time; whether the employee has studied the exit routes; whether the event is in an enclosed area or an outside switchyard; and whether the employee is in a bucket, in an aerial lift, or on a ladder. Field staff should evaluate and verify that, in the event of arc flash, they can exit the arc flash boundary within the assumed exposure time.

This discussion demonstrates the basic principles and thought processes involved when using exposure time as a basis for calculating the incident energy.