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Electrical Hazard/Risk Assessment and NFPA 70E

The concept of hazard/risk assessment and mitigation is a central theme within NFPA 70E, Standard for Electrical Safety in the Workplace. How can risks be reliably identified, how can they be managed, under what circumstances should they be accepted or rejected and, especially, how are they likely to be interpreted or 'perceived' by different people? NFPA 70E requires that a process be included in a facility's electrical safety program for evaluating electrical hazards and risk. From NFPA 70E, Article 110.7(F):

> "An electrical safety program shall identify a hazard/risk evaluation procedure to be used before work is started …where an electrical hazard exists. The procedure shall identify the hazard/risk process that shall be used by employees to evaluate tasks before work is started."

Risk assessment is widely recognized as a systematic process for quantitatively (or qualitatively) describing risk. Risk is commonly described as a combination of the *likelihood* of an undesirable event (accident) occurring and its consequences. Another way of looking at risk is as a mathematical combination of an accident's event probability of occurrence and the consequence of that event should it occur. Therefore, determining risk generally amounts to answering the following questions:

1. What is the hazard?
2. What are the consequences of the hazard?
3. What is the probability that something will happen?

1. What is the hazard?

The answer to the first question is a set of accident scenarios, or hazards. For electrical safety in the workplace, this translates into the three known electrical hazards of electric shock, electric arc flash, and electric arc blast.

2. What are the consequences of the hazard?

The second question estimates the consequences, or extent, of the hazard. As an example for arc-flash hazards, this can be quantified by evaluating the incident energy, in cal/cm^2, associated with an arc-flash event at a given location within a facility's electrical infrastructure. IEEE 1584-2002, *Guide for Performing Arc Flash Hazard Calculations*, can be used for quantifying the extent of an arc-flash hazard for three-phase circuits that are less than 15 kV. Based on an arc-flash analysis, one can determine the consequences, or extent, of the hazard and provide safety precautions, accordingly.

For shock hazards, the consequence is electrocution and is more difficult to quantify. Most requirements are provided through OSHA requirements in the form of mitigation through the application of energy source controls (i.e., de-energize to eliminate the hazard) or PPE requirements based on the voltage levels. However, it is understood that the extent of the hazard is a function of the voltage level, where typically the higher the voltage, the higher degree of shock hazard.

3. What is the probability that something will happen?

The third question requires the evaluation of the probabilities associated with these hazards. This is a much more difficult question to answer. This involves the development of a probability of occurrence based on the task being performed and the influences of other contributing factors. A form of task analysis is to be provided for the tasks to be performed. Per NFPA 70E, Annex F, Hazard Risk Evaluation Procedure, this task analysis should include "a comprehensive review of the task and associated foreseeable hazards that use event severity, frequency, probability, and avoidance to determine the level of safe practices employed." Further, for this task analysis, consideration should be given to the following step-by-step process: [from NFPA 70E, Annex F]

1. Gathering task information and determining task limits.
2. Documenting hazards associated with each task.
3. Estimating the risk factors for each hazard/task pair.
4. Assigning a safety measure for each hazard to attain an acceptable or tolerable level of risk.

Other contributing factors for determining the probability of electrical hazards are: [from NFPA 70E, Annex F]

1. Hazard exposure
2. Human factors
3. Task history
4. Workplace culture
5. Safeguard reliability
6. Ability to maintain or defeat protective measures
7. Preventive maintenance history

This listing could be expanded; however, it is indicative of the types of things that need to be considered when developing a probability distribution for a hazard. Quantifying these probabilities should be performed or supported by qualified people, since they are "trained and knowledgeable of the construction and operation of equipment or a specific work method and … trained to recognize and avoid the electrical hazards that might be present with respect to that equipment." [NFPA 70E, Article 110.6(D)(1)]

Incorporating Hazard/Risk Evaluation into the Workplace

Given the discussion above, a question that should be asked is, can we use this process in evaluating electrical safety hazards in the workplace? And if so, can we develop work processes to accommodate safely performing electrical work on or near energized circuits? There are many who suggest that no work should ever be performed on or near an energized circuit. My view is that, although preferred, this is unrealistic in today's workplace. Some level of activity will always be required to adequately maintain the complex systems encountered in the workplace. The solution is, therefore, a combination of Hazard/Risk Evaluation with possible hazard mitigation requirements from OSHA and NFPA 70E.

The following case study exemplifies an approach of incorporating probabilities and task assessments to provide a Hazard/Risk Evaluation for performing various tasks in the workplace.

During an outage with the bus de-energized, a low-voltage breaker was removed from a power distribution center, maintained and tested, and reinstalled in the distribution center. As is always recommended, the breaker was left in the open, or tripped, position when reinstalled into the de-energized power distribution center. To close this breaker, the closing springs must be manually charged. Unfortunately, the breaker was not manually charged prior to the distribution center being re-energized. Thus, when it came time to remotely close the breaker on the energized bus, the breaker would not operate. To charge this breaker so that it will operate, the door to the breaker cubicle must be opened and the charging lever operated. By analysis, this particular power distribution bus had been determined to have high incident energy potential and, therefore, could present a significant arc-flash hazard when energized. The question was asked: "What safety precautions should be implemented to ensure worker safety while charging the breaker?" The plant safety manager stated that all breaker operations performed with the door open require PPE to the full extent of the hazard. Plant workers considered that requirement to be excessive given the construction of the breaker cubicle and the task being performed. The following Hazard/Risk Evaluation could apply.

What is the Hazard?

The construction of this power distribution center is such that with the door open there is no shock hazard. However, there still may be an arc-flash and blast hazard, so it should be considered.

What are the consequences of the hazard?

As stated above, this particular power distribution bus has been analyzed and determined to have high incident energy potential and, therefore, could present a significant arc-flash hazard when energized. Based on the arc-flash analysis, the consequence, or extent, of the hazard is known in cal/cm^2.

What is the probability that something will happen?

1. *Gather task information and determining task limits* – For this particular task, charging the breaker engages the operating mechanism so that the spring-assist operation of the breaker is available to operate. In evaluating this task, one must be aware of the design and construction of the breaker. Some GE breakers have been known to close on the last charging stroke. Further, breakers have been known to inadvertently operate upon charging due to misalignment of the operating mechanism. For this particular breaker, the act of charging the breaker should not operate the breaker. Operation of this breaker requires additional action from either a protective device or manual operation. Therefore, the probability of this breaker closing while performing the charging operation is low.

2. *Documenting hazards associated with each task* – The potential incident energy of an arc- flash incident has been analyzed and determined to be a Hazard/Risk Category 3 (HRC-3), or in the range of >8 cal/cm^2 up to 25 cal/cm^2. This incident energy is associated with an exposed, energized circuit part in a box. There is no shock hazard

associated with this task. Due to the construction of this breaker and associated cubicle, there will be no direct exposure to the energized circuit parts.

3. ***Estimating the risk factors for each hazard/task pair***

a. Hazard exposure – There is minimal exposure to the hazard since the breaker is already racked in, and there will be no movement of the breaker to connect to, or disconnect from, the power bus during the performance of the charging operation. Due to the construction of this breaker and associated cubicle there will be no direct exposure to the energized circuit parts. Once charged, the breaker will be closed remotely with the door closed.

b. Human factors – Because of the arc-flash analysis for this facility, remote operation capability has been added for this breaker. In addition, a process for tripping and closing the breaker has been established, which includes having the affected workers located away from the breaker during planned operations.

c. Task history – In general, there is minimal, if any, documented history of incidents occurring while the breaker is being charged. This task history enhances the low probability of an incident during a charging operation.

   Note: Had this task been the racking-in or - out of the breaker on an energized bus, this would have a much higher probability of incidence. This assertion is based on NFPA 70E, Table 130.7(C)(9). This table was developed such that the Hazard/Risk Category provided for exposed, energized work is representative of the analytically determined incident energy associated with the assumed conditions for the circuits. It is noted that the table increases Hazard/Risk Categories when performing a breaker racking operation. The Hazard/Risk Category for tasks, other than working on energized circuits, were derived through a consensus of committee members based on their experience and a thorough review of reported incidents and associated injuries. They are not analytically determined or based; however, they are consistent with the process of having experts establish a probability distribution within a risk assessment.

d. Workplace culture – Safety for this facility is a priority. The workers are qualified and, thus, knowledgeable of the safety considerations as well as the construction and operation of this device. The fact that they recognized the potential hazard and involved supervision and the safety manager in determining the necessary safety precautions and PPE requirements is evidence of the workplace culture and the workers' qualifications. This workplace culture enhances the low probability of an incident.

e. Safeguard reliability – These breakers are well maintained and located in an environmentally-controlled MCC room with limited access. This safeguard reliability enhances the low probability of an incident.

f. Ability to maintain or defeat protective measures – As stated above, these breakers are well maintained and located in an environmentally-controlled MCC room with limited access. Excluding the opening of the hinged, cubicle door to accommodate the charging operation, all other protective measures will be maintained during the performance of this work. These protective measures enhance the low probability of an incident.

g. Preventive maintenance history – This facility is very active in performing preventive maintenance on their electrical infrastructure. Further, their electrical preventive maintenance (EPM) program is well documented and is based on applicable NETA standards. The preventive maintenance that had just been completed on this breaker provided documentation that the breaker was operating correctly, including the charging mechanism of the breaker. This preventive maintenance history enhances the low probability of an incident.

4. ***Assigning a safety measure for each hazard to attain an acceptable or tolerable level of risk***

   The arc-flash hazard for the applicable power distribution bus when exposed and energized is known and quantified as a Hazard/Risk Category 3, or up to 25 cal/cm^2. However, the probability of an arc-flash incident during a breaker charging operation is very low when considering the hazard exposure, task history, workplace culture, and preventive maintenance history. To establish a safety measure and an acceptable or tolerable level of risk, information from Table 130.7(C)(9) will be used. As stated above, this table was developed such that the Hazard/Risk Category provided for exposed, energized work is representative of the analytically determined incident energy associated with the assumed conditions for the circuits. It is noted that, typically, the table enables a drop of up to two HRCs when performing switching operations on an energized circuit with the doors closed (not exposed circuit). For these breakers, charging a breaker with the door open should involve even less risk to the worker since the likelihood of a breaker closure onto an energized bus during the charging operation is minimized through equipment design, construction, and proper preventive maintenance. Based on the risk factors for this task, a reduction of two HRCs, or a reduction to an HRC-1 level at a minimum for this specific task and equipment should be adequate to protect the worker.

Although some may feel that all risk to an electrical worker should be mitigated through the use of energy source controls, PPE requirements, and special precautionary techniques, there is benefit in combining risk assessment with current OSHA and NFPA 70E requirements to accommodate less hazardous work activities. All electrical tasks, as presented in NFPA 70E Table 130.7(C)(9), do not have the same level of risk. To effectively perform electrical tasks and protect qualified workers, the equipment design and condition, the task being performed, and the experience and capabilities of the qualified worker should be evaluated and included in the risk assessment. This inherent difference in risk levels could be accounted for through the judicious application of risk assessment techniques, while allowing for adequate risk mitigation.

As Operations Manager of ESCO Energy Services Company, Lynn brings over 25 years of working knowledge in design, permitting, construction, and startup of mechanical, electrical, and instrumentation and controls projects as well as experience in the operation and maintenance of facilities.

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