Removing Yourself from Hazards During Equipment Operation

The safest way to work around electrical equipment is to turn it off. This is usually required by OSHA and NFPA 70E, but with some exceptions. When performing switching, the danger is in the process of turning the equipment off/on, voltage testing and applying grounds to assure an electrically safe work condition. This paper will focus on the process of operating equipment in order to turn the equipment off and verifying the equipment is de-energized.

SHOCK BOUNDARY REVIEW:

First, a review of the electrical protection boundaries may be needed. The shock boundaries are voltage dependent boundaries and vary by system nominal voltage. They are outlined in NFPA 70E, Table 130.2(C). These are the Limited, Restricted, and Prohibited Approach Boundaries and are distances from *exposed energized* conductors. The first hazard discussed here is a possible confusion in knowing the proper voltage boundary.

NFPA 70E Table 130.2(C) lists 14 voltage ranges in five columns which are potentially 70 distances. Definitions of Limited, Restricted and Prohibited Boundaries can be confusing. The boundaries are in effect for exposed energized conductors. These distances should apply when the covers are off and before the circuits have been de-energized, locked out, tested and grounded, if necessary. For most purposes discussed here, the Limited Approach Boundaries of 3.5 feet for low voltage equipment and five feet for medium voltage equipment are applicable. You should barricade an area at least five feet around the equipment and require PPE for anyone entering this barricade. This barricade may be moved out further to encompass the arc flash boundary or for other personnel safety reasons. Do not place barricades where they will interfere with the work or will cause an increased hazard should something go wrong.

ARC FLASH BOUNDARY REVIEW:

According to NFPA 70E, appropriate PPE shall be worn when working within the Arc Flash Boundary. The arc flash boundary is in effect anytime there is an arc flash hazard. Article 100 of the NFPA 70E defines the arc flash hazard as: “A dangerous

condition associated with the possible release of energy caused by an electric arc." FPN No. 1 clarifies:

> *"An arc flash hazard may exist when energized electrical conductors or circuit parts are exposed or when they are within equipment in a guarded or enclosed condition, provided a person is interacting with the equipment in such a manner that could cause an electric arc."*

This interaction includes operating and racking breakers, removing covers, voltage testing, and applying grounds. This boundary may be calculated along with the arc flash incident energy or may be chosen with the aid of NFPA 70E. According to NFPA 70E, Article 130.3(A)(1), a four foot arc flash protection boundary is recommended when calculations are not performed for low voltage equipment with available power not exceeding 100 kA cycles. Large industrial equipment will almost always exceed this value.

The arc flash boundary should be calculated for medium voltage equipment. Tony Demaria Electric defaults to a ten foot boundary and 40 cal/cm^2 rated PPE when operating medium voltage equipment.

Calculating the arc flash boundary can be a daunting task, especially when in the field with minimal information and resources. One of four different methods may be adopted from NFPA 70E Annex D. Alternatively, Tony Demaria Electric has devised a slide rule method for estimating the incident energy and boundary distances. This method involves using the upstream transformer and estimated motor load information to derive the available fault current and comparing this with the estimated clearing time to establish the arc flash hazards. This can be seen in Figure 3. This slide rule is good up to 1000V and a 6MVA transformer. This slide rule will be distributed at the NETA PowerTest Conference.

COMMON SENSE:

It has been said that "Common sense is the knack of seeing things as they are, and doing things as they ought to be done." It is time to apply some common sense to electrical injuries. If any of these actions is likely to cause an arc flash event, then how do you avoid injury? Frequently, many people start the protection method with PPE.

PPE should always be a last safety resort. In any unsafe situation, the goal is to remove the hazard so that PPE is not necessary.

There are several methods that avoid this, but many are not yet in common usage. To do things as they ought to be done means removing yourself, and others, from the shock and arc flash boundaries while establishing an electrically safe work condition. In order to do this, the whole process needs to be thought through and planned ahead of time.

PLAN THE JOB:

Before equipment is operated, first check the condition of the gear. Are there any panel meters or voltage indicators present? Do they appear to be working properly? Are the correct panel lights lit? In what order should the equipment be shut down? Can the loads be turned off remotely or further upstream or downstream where the hazards may be lower? Are there any additional hazards that could be introduced by turning this equipment off?

All warning labels should be read and understood by those doing the switching. The equipment should also be checked against the single-line drawings and all loads checked. It may be necessary to check with operations before turning off or on certain equipment. If you will be shutting down life safety systems, control power, or backup power systems, preparations should be made for alternate protection methods.

Arc Flash and voltage PPE that may be necessary should also be assessed and checked. The arc flash warning labels should be observed. If it is necessary to operate any equipment that has arc flash hazards over 40 cal/cm^2 at the working distance, alternate methods of operating should be evaluated.

LOOK-ALIKE EQUIPMENT:

One of the first steps to take before operating or working on any equipment is to make sure that you are working on the right piece of equipment. There have been many documented cases of personnel either operating the wrong equipment or entering the wrong cubicle after one cubicle has been turned off. Operating the wrong equipment can result in anything from embarrassment, as people come to investigate why their lights and computers went down, to injury to persons and loss of money because the wrong process was shut down or safety systems were turned off. Entering

the wrong cubicle can result in death. The job scope should be explained to all personnel involved. Another part of the job briefing should be an explanation of the hazards of entering the wrong equipment and an explanation of why the other equipment may not be de-energized.

Equipment that is to be worked on should be marked so that others know where the work is taking place. This can be accomplished by taping off the area and posting warning or danger signs on the equipment. Different methods have been adopted by different people and companies. When working outdoors, it may be necessary to use plastic chain or rope to avoid loose tape that serves no purpose or gets wrapped around the wrong object, directing people to the wrong equipment. Signs should always be posted on the barricade so that others are aware of the hazards.

NOT GETTING DISTANCE! (In Certain Circumstances):

There may be situations where the equipment cannot be shut down due to operational limitations or troubleshooting. In these circumstances, when working inside shock and arc flash boundaries, all precautions should be taken to ensure that the hazards are minimized and that the risk factor for the work to be performed is reduced as much as possible. Besides donning PPE, other mitigation factors may be utilized. Barriers should be erected between yourself and any energized equipment that is not part of the work scope. Arc flash blankets and/or rubber blankets should be put up where possible. These should be secured properly and in accordance with manufacturer's recommendations. Barricades should also be put up and remove unauthorized, unqualified, and unnecessary personnel from the work area. As a minimum, these barricades should be at the greater of the Limited Approach or the Arc Flash Boundaries. Ensure that everyone in the area knows of the work to be performed and is apprised of the hazards to themselves and to those working in the equipment.

GET DISTANCE!:

When turning equipment on or off, there are several options. There are engineered options such as using computer control to operate breakers from a distant operations center on the computer. Mimic panels can be used to operate the equipment from outside of the boundaries or outside of the room. There are aftermarket

options that attach onto the front of the switchgear and will operate switches while allowing the operator to stand away on a cord or wireless signal.

When none of these options are available, there is also an old tried and true rope and pulley system (see figure 1). This is not known or used by many people. It does not work for all applications, but excels in switching load interrupter switches, many medium voltage starters and many old-style OCB's. Using the rope and pulley system, a rope is attached to the operating handle or pull ring and run through a pulley(s) if necessary. In this way the operator can stand away from and to the side of the equipment and operate the equipment. This method is cheap, easy to set up and available to everybody.

If you must stand close to the equipment to operate it, there are a few other things you can do to keep yourself from being injured. Stand to one side. Wear gloves. When wearing a face shield and balaclava instead of a full hood, face the equipment to avoid collecting a fireball inside the shield. Arc Flash blankets can be used to redirect the blast as well.

Racking out a breaker is strongly preferred and usually the only way to provide adequate separation in establishing an electrically safe work condition. Many dangers exist during this step as well. Again, there are many methods that can be used to remove yourself from the hazards. Some equipment may have built-in electrically operated racking mechanisms that will allow the operator to rack the equipment outside of the flash protection boundary. There are also many aftermarket products or robots which may be employed to rack breakers either at the end of a long control cord, or remotely via wireless control. Some of the remote racking devices come with a remote camera, or may be fitted with one at a later date.

If you must rack the breaker out locally, there are additional things to remember. Use closed door racking whenever possible, even though the door will most likely blow open. Wear the proper rated PPE. Stand to the side if at all possible. If using a hand crank, use an extension on the crank handle to increase your distance from the equipment and possible arcing location. You can weld an additional section onto your factory-furnished crank handle (see figure 2). Even an additional few feet can drastically reduce the calories per centimeter squared on your body exposure. As an example, a 42 cal/cm^2 exposure at 36 inches on medium voltage switchgear will be reduced to 21 cal/cm^2 at 72 inches.

OPENING DOORS & COVERS:

The next task that must be accomplished is to open covers in order to test for absence of voltage. This seemingly easy task can introduce additional hazards. The cover can slip and fall into the gear. There may be loose hardware that is leaning against the cover that could fall when the cover is removed. Full PPE will be necessary for this task when inside the shock or arc flash boundaries.

When opening hinged covers, care should be taken not to position yourself so that you are in the path of the arc flash or blast. Keep the door between yourself and the exposed conductors until you are sure there are no additional surprises waiting inside. When removing a cover without hinges, get some help with the cover. Do not take all of the bolts out right away. With bolts still on one side, the cover can be opened slightly and the interior observed without taking the chance of dropping the cover into the equipment. Another method that is used is to leave one bolt in a corner and rotating the cover off. In this way the cover is prevented from falling into the gear and remains attached with less chance of getting damaged.

Suction cups can be very helpful when removing covers without handles. Make sure the suction cups are placed on a clean, dry, flat surface. These cups are relatively inexpensive and can be used to avoid dropping the cover into the equipment. Lean the cover out slowly at first and listen for any unexpected noises. Any scraping against the cover from loose parts, or the hissing or crackling of ionized air is a warning sign that more trouble could be coming. This should be investigated before continuing with the task.

VOLTAGE TESTING:

In order to test for voltage, the live-dead-live method should always be employed. Panel meters or auxiliary voltage indicators may be used as additional verification. Do the panel meters that you looked at before de-energizing the equipment show an absence of voltage now? Have the voltage indicators that were lit beforehand been put out? Even with these checks, it is often difficult to get around going into the equipment. Full PPE will now be necessary if crossing any of the shock or arc flash boundaries.

When testing for medium voltage equipment, the meter should be placed on a hot stick. Use the best tester available. Do not choose to save money here. Using the hot stick will allow you to stay out of the equipment while performing your test. Always

extend the hot stick to its full length. Always test all three phases. Start with the highest voltage expected in the equipment, then lower the test range. A contact tester with a low range setting should be used after a proximity tester has been exhausted in order to test for induced voltage conditions. If a hot stick is not practical to use, always use gloves rated for the full system voltage for this task when crossing either the restricted or prohibited approach boundaries. Using a contact tester, test all three phases to ground as well as phase to phase.

GROUNDING:

Now that absence of voltage has been verified, grounds may be applied. Grounds should always be used when working on equipment rated above 1000V and are recommended for low voltage equipment whenever back feeds or inductive coupling may be present. Once again, the goal is to remove yourself from the hazard area.

With this in mind, there is another way to apply grounds remotely. Grounding cubicles have been around for some time. They are not in common use. They are a common sense approach to applying grounds safely. However, in some situations, they have a huge disadvantage. That is, some cubicles have an energized top feed and some cubicles have an energized bottom feed. This is especially typical in tie breakers. Using a grounding breaker with the wrong side grounded could lead to catastrophic damage. Always be careful with confirming the proper configuration of grounding breakers prior to installation. The grounding breaker may be inserted into a cubicle and then operated remotely from system controls or mimic panels, or if necessary, from a robot operator. Keep in mind, if they need to be racked into the cubicle, this should also be done remotely, if possible. If not, follow the same precautions as discussed earlier for racking equipment out.

If grounds cables or clusters must be applied manually, use a hot stick. Remember again, distance is your friend. Even after the voltage testing and verification, the circuit could still be hot. This is common sense as many an experienced electrician can relate a story of applying grounds and having the unfortunate experience of touching an energized conductor with the ground cluster. Not a pretty picture! The good news is, if the grounding cluster has been sized properly and is being installed correctly, it usually trips the upstream breaker possibly causing damage to equipment but not injury to the electrician. Remember, the correct

installation procedure is to apply the ground hard and fast. Never attempt to strike the ground and draw the arc. Once again, hot sticks can be lengthened and body position becomes important. Don't stand in the path of the hazard!

SUMMARY:

By thinking through and planning each step, the process of establishing an electrically safe work condition can be done safely and without exposing yourself to unnecessary hazards. Once the equipment is de-energized, locked out, tagged out, tested for voltage, and grounded if necessary, an electrically safe work condition has been established. Now that this has been done safely and the electrical hazards have been removed, the original work task(s) may begin.

Figure 1: Medium Voltage Load Interrupter Switch Operation with Rope and Pulley System

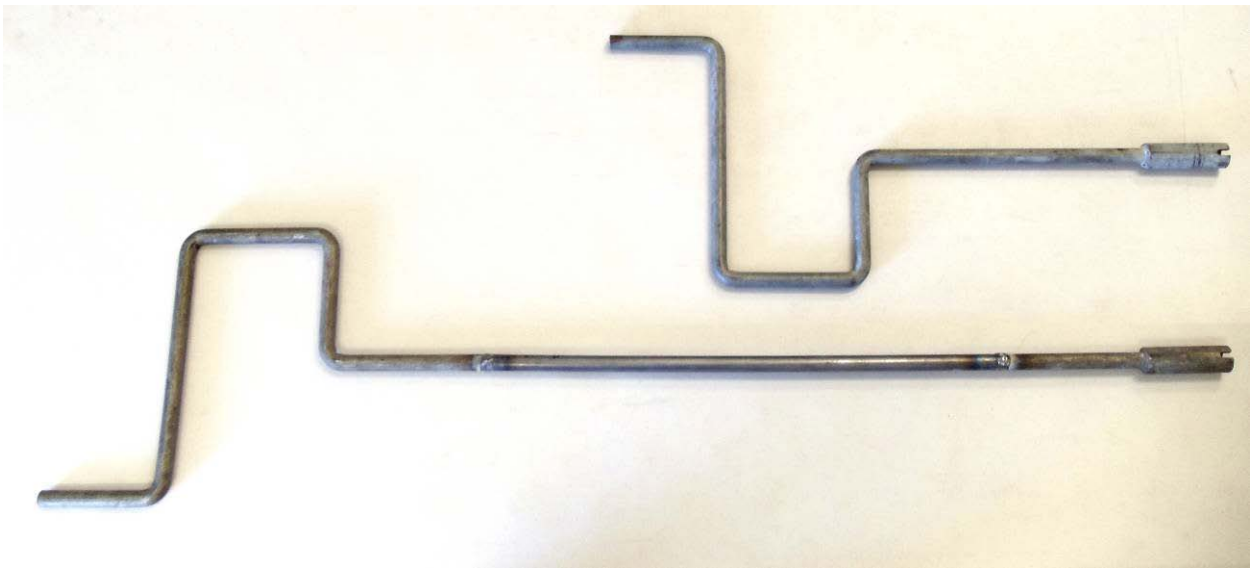

Figure 2: Factory Racking Handle with two foot extension welded on

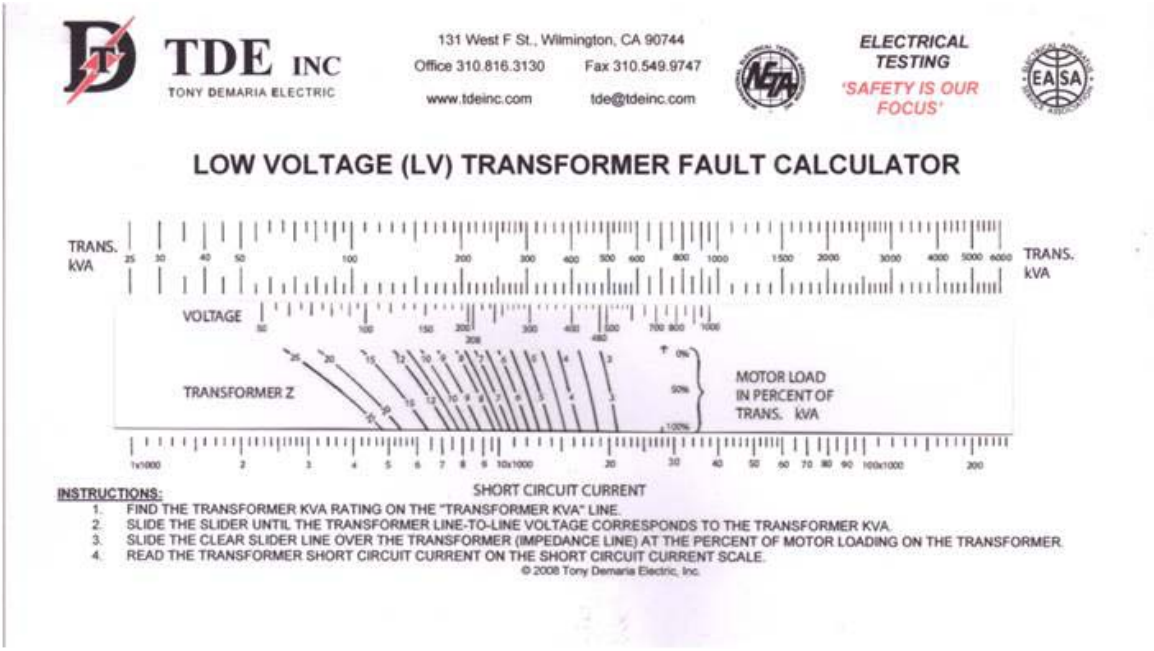

Figure 3: Tony Demaria Arc Flash Slide Rule