FLASH HAZARD ANALYSIS: DETERMINING DANGER LEVELS OF WORKING ON ENERGIZED EQUIPMENT

By Fred Tanguay

The traditional hazard we all equate with performing energized electrical work is contact with a live part or conductor, resulting in electrocution and possible death. The Occupational Health and Safety Act states that "The worker shall use rubber gloves, mats, shields and other protective equipment and procedures adequate to ensure protection from electrical shock and burns while performing the work". It further states that "If the equipment is operating at a voltage over 300 volts a trained competent worker must be present and capable of performing rescue operations."

When you take a close look at the post mortem results of contact incidents, you will find that most of these incidents involved burns resulting from a flash after contact with the energized part.

An electric arc can produce temperatures in excess of 20,000°C. This intense heat develops a shock wave of superheated ionized gas containing flying debris such as melted conductors, structural steel and insulation. The force associated with the shock wave is equivalent to one stick of dynamite for every MVA of fault power. A fault level of 40MVA at 600 volts is not uncommon. The ability of our unprotected skin to withstand this extreme temperature is very poor. In Fact, temperatures of 80°C for 0.1 seconds will cause a second-degree burn.

Figure 1: 3000 amp 600 volt bus fault

The electrical industry has struggled with these facts for years knowing that there is an extreme danger when performing energized work. Through organizations such as ANSI, E&USA, IAPA, WSIB, CSAO, IEEE and NFPA a method of determining the danger level, known as Arc Flash Analysis, was developed. The purpose of the analysis is two-fold. First, to determine the level of energy caused by various types and configurations of power system faults known as the Incident Energy. The second factor is to calculate the distance from a fault to an object such as a person where the Incident Energy drops to a level of 1.2 cal/cm2 for a fault duration > 0.1 sec or 1.5 cal/cm^2 for a fault duration of < 0.1 sec. This is the amount of energy required to produce a second-degree (Curable Burn) on unprotected human skin. This distance is known as the Flash Boundary.

The key factors needed to determine the Incident Energy are the available fault level expressed in MVA and the fault duration expressed in seconds. This data is available from your Protective Device Co-ordination Study and the System Short Circuit Analysis. The Co-ordination Study provides the total clearing time of the various fuses, circuit breakers and protective relays. The Short Circuit Analysis provides the necessary fault level information.

Other factors affecting the accuracy of Flash Hazard Analysis are system voltage, number of phases and the location of the arc either in open air or confined in a box. IEEE standard 1584 and NFPA Std 70E provide Detailed equations to calculate the incident energy, such as the following example.

$$E_{MA} = 5271(D)^{-1.9593}(T)\left[0.0016F^2 - 0.076F + 0.8938\right] \quad (1)$$

$$E_{MB} = 1038.7(D)^{-1.4738}(T)\left[0.0093F^2 - 0.3453F + 5.9675\right] \quad (2)$$

Where:
EMA = The incident energy in air @ 600volts
EMB = The incident energy in box @ 600volts
F = Three phase fault level
T = Trip time or arc duration
D = Distance from the arc source.

As an example, if we examine a 600-volt system that has a fault level of 45MVA and a trip time of 0.33 seconds, we derive an incident energy of 30.48 cal/cm2 at a distance of 18 inches. This level of energy would be devastating to an unprotected worker or observer. If this same fault were in a box or switchgear cell the incident energy would be 800,000 cal/cm2.

We can now use the incident energy level to select flame-retardant clothing and equipment to protect the worker from this hazard. A publication such as NFPA 70E provides excellent guidelines on this matter. From table 3-3.9.3 we find our example is greater than Hazard Class III at 25 cal/cm2 and less than Hazard Class IV at 40 cal/cm2. Based on this, we must select protective equipment that will provide an Arc Thermal Protective Value of at least 30.48 or greater, or Hazard Class IV protection.

For this method of calculations to work, it is essential that the protective device performance match the settings prescribed by the protective device co-ordination study. This is often not the case. The settings in the field are not the same as those prescribed by the study and up-to-date studies are rarely available. Finally, the available fault current level calculation must be as accurate as possible. Errors made here can have devastating results.

From the Typical Time current plot in figure 2, we see that at a fault level of 32kA the breaker trip time is 0.3 seconds. This equates to an incident energy of 14.9 cal/cm2. However, what happens to the incident energy if we have made an error and overestimated the short circuit level? We would end up setting the short time or instantaneous protection higher than needed. In reality, if the breaker sees a bolted fault current of 20kA, the actual fault clearing time is 4.4 seconds. The resultant incident energy is now 80.3 cal/cm2. You can see that

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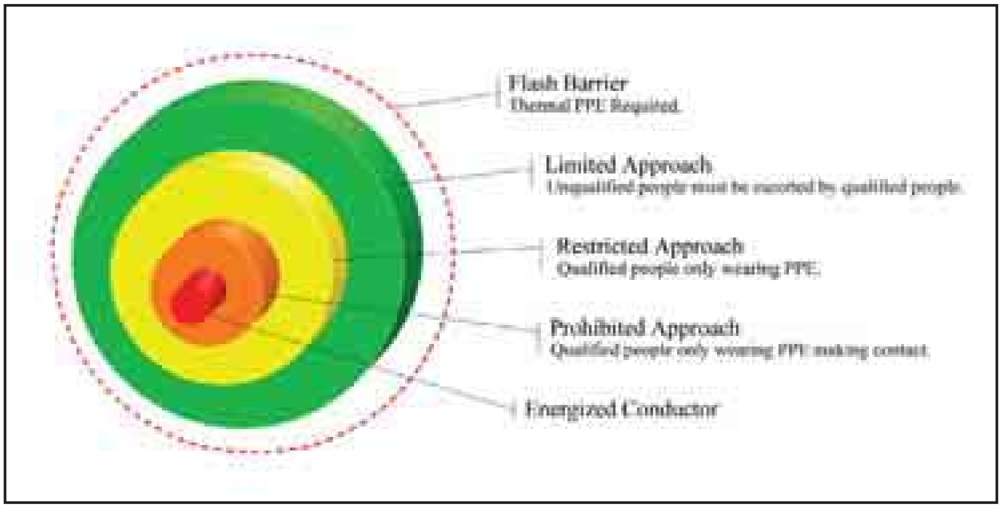
even though the fault level is greatly reduced the incident energy is increased by a factor of seven times. In fact, no level of thermal PPE would protect a worker. The results would most certainly be fatal.

The second purpose of Flash Hazard Analysis is the determination of the Arc Flash Barrier Distance. This distance is again defined as the distance from an arc where the incident energy is equal to 1.2 cal/cm2 where TArc>0.1 sec or 1.5 cal/cm2 where TArc<0.1sec. Once again, the key variables to the equation are the fault level and the fault duration.

The safe working distance from an arc is expressed as:

$$D = [2.65 x MVA_{bf} x T]^{1/2} \quad (3)$$

$$\text{or } D = [53 x MVA_{bf} x T]^{1/2} \quad (4)$$



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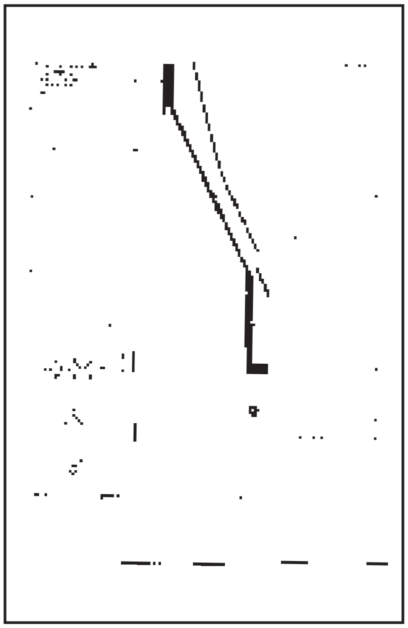
These equations allow you to predict the safe distance from an arc where an unprotected person will receive a second-degree burn. This is very useful information for an unprotected observer who may be witnessing energized work or power switching. Based on the previous example, the Flash Barrier would be equal to 6.3 feet.



Typical Time Current Characteristics

Today's power system is in a constant state of flux. Efficiencies are increasing and impedance is falling. The use of parallel and automated systems to improve reliability has also contributed to higher fault levels. As equipment ages and less maintenance is provided, power systems tend to fault more frequently. Finally, the technical skills of our workers are increasingly challenged by the lack of time, limited manpower and increased job scope.

As managers, supervisors and workers, it is our responsibility to take a better look at the hazards that we expose ourselves to when presented with the daunting task of performing any type of energized electrical work. By applying analytical tools such as Coordination Studies, Short Circuit Analysis and Arc Flash Hazard Analysis we are able to optimise our power system's performance. We can then make our workers aware of the danger areas in the system so the necessary safety precautions can be taken during system operation and maintenance.

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