THE HEAT OF THE MOMENT!
THE COMPLEX HAZARD OF ELECTRIC ARC FLASH EXPLAINED

Abstract

Electric arc flash and the considerable hazard it presents to personnel working on, or near to, live electrical equipment, are explained, as are the recommended measures that need to be taken to eliminate or minimize this risk and hence to ensure safety and compliance with the law.

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INTRODUCTION

On 1 February 2007 at an office building in Shoe Lane, central London, two technicians were installing a capacitor to help reduce energy consumption at the site. One of the workers was fitting cables in the back of the capacitor, which was positioned above a number of live conductors. The cables came into contact with one of the conductors and caused an electric arc flashover. The worker suffered severe burns to his face and upper body, horrific injuries that have prevented him from returning to work. The health and safety manager who had overall responsibility for safety procedures was found guilty and fined £2,500 and ordered to pay £5,500 in costs. The company pleaded guilty to breaches of the Health and Safety at Work Act and was fined £25,000. Since the incident, the company has introduced a Point of Work Risk Assessment form and ensures that engineers who may be at risk are provided with flame-resistant overalls when working in switch rooms.

Electrical flashover, or arc flash, is one of the most deadly and least understood hazards of electricity and is prevalent in most industries. Each year around 1,000 electrical accidents at work are reported and as many as 25 people die from their injuries [1]. It is widely recognised that the higher the voltage of an electrical power system, the greater the risk for people working on or near energised conductors and equipment. However, the effect of the thermal energy released in an arc flash can actually be worse (and such incidents occur more often) at lower voltages, and can cause devastatingly severe burn injury and even death.

WHAT IS AN ELECTRIC ARC FLASH?

An arc flash is usually caused by inadvertent contact between an energised conductor, such as a bus bar or wire. with another conductor or an earthed surface. When this occurs the resulting short circuit current will melt the conductors, ionise the air and create a conducting plasma fireball with temperatures in the core of the arc that can reach upwards of 20,000 °C.

Severe injury and even death can not only occur to persons working on the electrical equipment but also to people located nearby.

Arc flash injury can include external burns to the skin, internal burns from inhaling hot gases and vaporised metal, hearing damage, eye damage such as blindness from the ultraviolet light of the flash as well as many other devastating injuries. Depending on the severity of the arc flash, an explosive force known as an arc blast may also occur, which can result in pressures of over 100 kPa, launching debris as shrapnel at speeds up to 300 m/s.

Survivors of such injuries may require extensive treatment and rehabilitation and the cost of these injuries can be extreme, physically, emotionally and financially. Although legislation requires businesses to perform risk assessments for all work activities, electric arc risk is often overlooked because most people are unsure how to assess and manage this hazard effectively.

WHICH ORGANISATIONS, WORKPLACES AND TYPES OF WORK ARE MOST AT RISK?

All industries have a level of risk, but there are, of course, those that carry a higher risk, such as utilities, energy producers and providers, mining, manufacturing companies (particularly those in the food, pharmaceutical and chemical sectors), hospitals, large commercial organisations, data centres, education establishments and large leisure facilities.

For low voltage work, the following is a list of those activities that have the potential to initiate an arc (and some of which have been shown to be common causes of electrical flashover) -

- Connecting cables into live equipment
- Testing; especially with substandard instruments and test methods
- Testing on damaged cables and equipment. There are several known cases of arc flash due to using voltage indicators on faulted cables
- Inspections or any interactions which involve the exposure of live voltage conductors
- Work on, or adjacent to, live low voltage conductors that are insulated but where the work may adversely

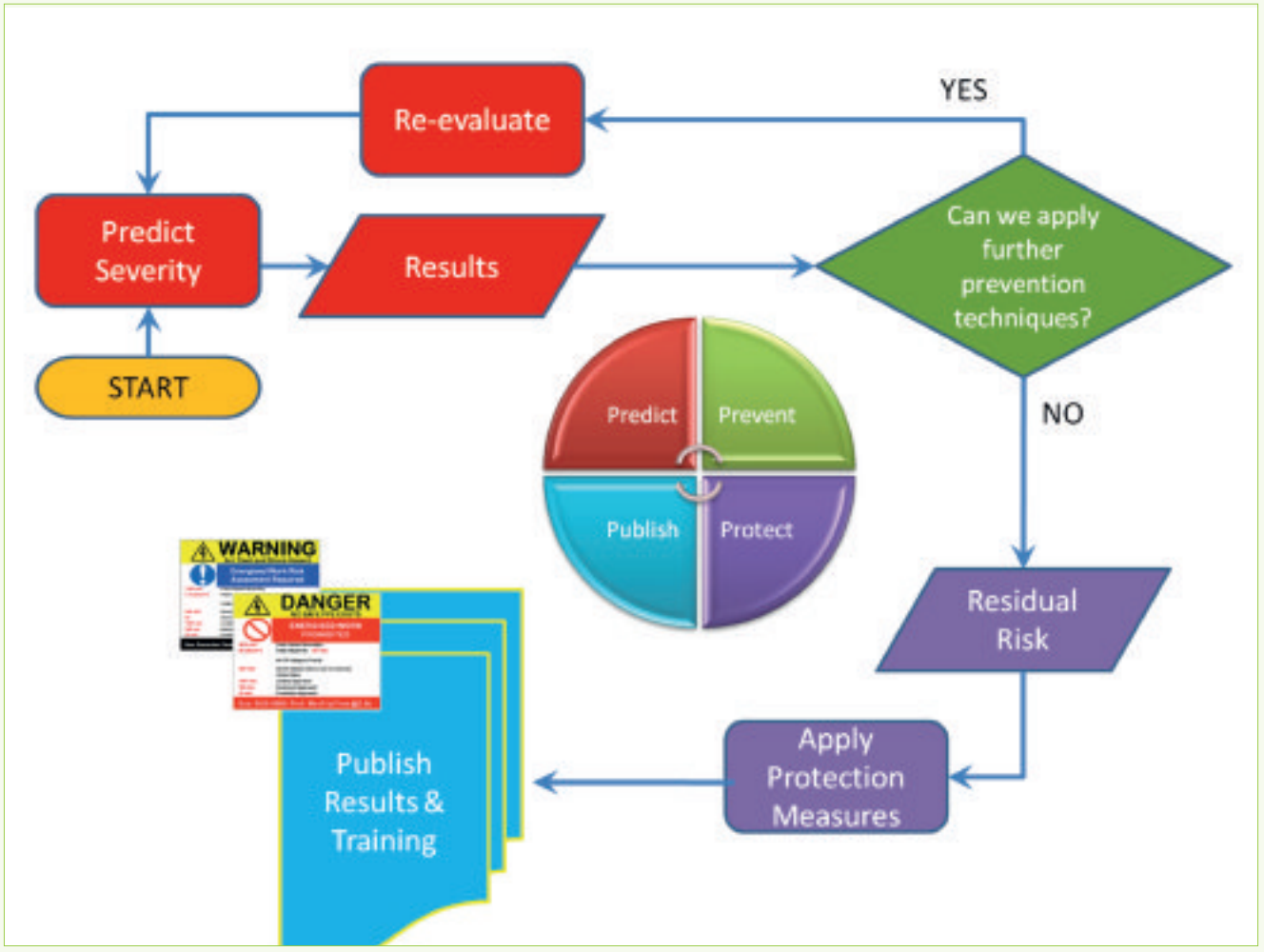

Figure 1 The DuPont Arc Guide approach.

affect the integrity of that insulation. Examples are drilling into panels and drawing cables into cable management systems

- Custom and practice activities such as installing or repairing equipment which is adjacent to exposed live low voltage conductors
- Removal and replacement/insertion of components such as circuit breakers into energised panel boards and large power bus bar tap off units
- Live underground cable jointing
- Switching and racking out poorly maintained or legacy LV switchgear
- Replacement of fuses and links especially onto faults

HOW TO MANAGE THE HAZARD

The arc flash hazard needs to be determined by risk assessment, out of which the decision to work live or dead and the required precautions will be derived. The need for risk assessment is embodied in European Law through Directive 89/391 (EU Workplace Health and Safety Directive) and the associated guidance which identifies electrical work as a 'high risk' activity.

The European Agency for Safety and Health at Work defines risk assessment as the process of evaluating risks to workers' safety and health from workplace hazards. It is a systematic examination of all aspects of work that considers –

1. What could cause injury or harm,
2. Whether the hazards could be eliminated and, if not,
3. What preventive or protective measures are, or should be, in place to control the risk

But a risk assessment should provide more information than this and it is advisable to adopt the step by step approach of Predict, Prevent, Protect and Publish (*see Figure 1*) that is recommended in the Arc Guide produced by DuPont Personal Protection [2]

Predict

The severity of the thermal effect of an arc flash is defined by the amount of 'incident energy' that a victim, standing at a given distance away from the arc, could receive to the surface of the skin. It can be quantified in units of kJ/m^2, J/cm^2 or cal/cm^2 – one cal/cm^2 being equal to 4.184 J/cm^2. Units of cal/cm^2 are most commonly used as this is specified for PPE garment labels according to the standard IEC 61482-2.

As a frame of reference for incident energy, an exposure to heat flux of 1.2 cal/.cm^2.s during one second, i.e. exposure to 1.2 cal/cm^2, can produce the onset of second degree burn to the skin. This value is used by many standards as the benchmark that defines protection against the thermal effects of arc flash and the threshold of a zone which is commonly known as the arc flash protection boundary. This is where the predicted incident energy falls to 1.2 cal/cm^2.

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The calculation methods in the DuPont Guide are taken from the IEEE 1584 Guide for Performing Arc Flash Hazard Calculations 2002 and take into account distance to worker, arc confinement, conductor gap, voltage, prospective fault current and disconnection time. These are accurate calculators to determine prospective fault current, which is always a key element in predicting arcing current and therefore the incident energy levels. The Guide includes charts and calculators that will help even when site data is limited, such as for circuit breakers and common European style fuses.

Prevent

Design out, eliminate or remove the hazard at its source. This leads to the conclusion that the majority of electrical tasks must be carried out with the equipment made dead. To work dead the electricity supply must be isolated in such a way that it cannot be reconnected, or inadvertently become live again, for the duration of the work. As a minimum, this will include the positive identification of all possible supply sources, the opening and locking of suitable isolation points by personal padlocks and for the proving dead at the point of work.

Where the arc flash hazard cannot be eliminated then suitable risk controls should be in place (preventive or protective measures). It is important to understand that the relationship between hazard identification, deciding on suitable risk controls and the decision for work to proceed is an inter-dependent one. Furthermore, the physical task to be carried out on or near energised equipment is a hugely significant factor as it is usually worker activities that initiate a damaging arc flash event. To further clarify this relationship, a decision for work to proceed where there is a significant arc flash hazard cannot be taken in isolation of other factors. The level of hazard and also the availability and effectiveness of preventive or protective measures will also need to be considered.

Article 6(2) of European Council Directive 89/391/EEC EU Workplace Health and Safety Directive states 'where an employer implements any preventative measures, he shall do so on the basis of the principles as follows:

1. Avoiding the risk
2. Evaluation of the risks that cannot be avoided
3. Combating the risks at source
4. Adapting to the individual
5. Adapting to Technical Progress/ Information
6. Replacing the dangerous by the non dangerous
7. Developing a coherent overall prevention policy
8. Giving collective protective measures priority over individual protective measures
9. Giving appropriate instruction to employees

These general principles of prevention should be considered against a hierarchy of risk controls with priority as follows:

1. Elimination of the arc flash hazard
2. Minimisation/engineering controls
3. Safe systems of work
4. Information and training
5. Personal Protective Equipment (PPE)

Protect

Where the risk cannot be controlled by prevention, or where there is a residual risk of injury, then it may be necessary to consider mitigation to prevent injury to the worker. The requirement for, and suitability of, mitigation techniques must form an essential element of any risk assessment. Many different forms of protection arrangements are referred to in the Prevent section of the DuPont guide, such as remote operations, reduction in arcing time through arc detection and rapid disconnection, and through training in operational techniques, such as body positioning, when operating equipment.

As a last line of defence it may be necessary to consider personal protective equipment (PPE) to prevent injury to the worker. Where protection against the thermal effects becomes necessary it must be emphasised that PPE does not prevent the accident happening in the first place.

PPE used for arc flash protection includes garments made from flame resistant (FR) fabric. This is designed to provide a thermal barrier and limit the incident energy exposure at the skin surface to no greater than 1.2 cal/cm2. FR clothing is rated on its Arc Thermal Performance Value (ATPV) in cal/cm2, or Breakopen Threshold Energy (EBT) in cal/cm2 according to EN 61482-1-1 and/or on its Class 1 or 2 performance according to EN 61482-1-2, with the arc rating certified according to IEC 61482-2. The ATPV is the limit of the incident energy up to which a material can be exposed, so that the curve of the energy transmitted through the material will remain below the Stoll curve, and without causing break open or - more colloquially - the ATPV is the incident thermal energy that the clothing can support before that the wearer will suffer 2nd degree burns.

To properly protect a worker, the ATPV value – or the EBT value in the event that no ATPV can be determined - of the FR clothing must exceed the prospective incident energy available at a given location at a given distance from the electric arc event. Non-flame-resistant clothing may ignite or melt at low incident energy and once ignited will continue to burn after the electric arc has been extinguished.

Publish

The European Council Directive 92/58/ EEC stipulates the minimum requirements for the provision of safety and/or health signs at work, stating that signs must be provided where hazards cannot be adequately reduced by techniques for collective protection or by measures, methods or procedures used in the organisation of work. Signs must be standardised across Europe to reduce hazards that may be accentuated with language and cultural differences, and they must warn of any remaining significant risk or instruct employees of the measures they must take in relation to these risks.

Arc flash hazard is a serious electrical risk that needs to be managed in many industrial environments and risk assessment for workers who operate in proximity to, or on, energised electrical equipment and cables is essential to ensure safety and compliance with the law.

REFERENCES

1. HSE Electrical Safety at Work, http://www.hse.gov.uk/electricity/index.htm
2. DuPont Arc Guide, www.arcguide.dupont.com