The image above captures an arc fault on a dummy fitted with an arc rated shirt and an arc rated face shield with chin return. The omnidirectional spray of copper droplets, with copper dripping from the end of the electrode, can be clearly seen at the extreme left of the photo above. The body is completely enveloped by the plasma cloud. The chin return dramatically reduced the impact of the fault on the face.

ENA'S ARC FLASH HAZARD REVISED

The recent release of ENA NENS 09 2014 sends a clear message that cotton PPE is not suitable for electrical workers, and electrical workers should wear a minimum of 4cal/cm^2 arc rated PPE on the arms, legs and torso, with higher levels of PPE for higher risk tasks or higher risk equipment.

By Brett Cleaves, Engineering Safety

Arc flash standards have been evolving since the 1980's. The research that precedes or follows each step of the evolution has greatly improved the understanding of arcing faults and their associated hazards. Likewise, equipment manufacturers have continued to develop products to help to control the hazards. Since 2002 IEEE 1584 has been the benchmark standard for quantifying arcing hazards in terms of incident energy. Continued research has highlighted a number of shortcomings in the standard, many of which are being addressed as part of the standards ongoing major revision.

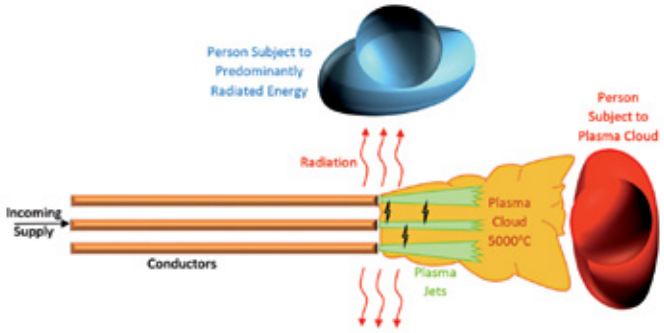
With known issues in the current Australian and International standards, and with probably the largest electrical workforce in Australia, Sydney metropolitan electrical utility Ausgrid recently initiated a process to review arc hazards and available PPE. Armed with the available information including research by Australia's own Dr David Sweeting, and its own Lane Cove testing station, Ausgrid commenced testing. The test adopted a horizontal bus bar arrangement that places the test dummy directly in the line of fire of the arcing fault and its products. The focus of the testing was to update the Ausgrid arc flash safety program, which in turn became part of the NENS 09 review and form the basis of the new heavily revised ENA NENS 09 2014 National Guideline for the Selection, Use and Maintenance of Personal Protective Equipment for Electrical Arc Hazards.

ENA NENS 09 2014

The single largest change in this version is that cotton PPE is out and arc rated PPE is in. The latest version incorporates the results of extensive testing and reasoning by Ausgrid's Mr Darren Jenkins, as well as his peers and the NENS 09 committee. The testing behind NENS 09 confirms that the opposing electrode arrangement used in IEEE1584 and the position of the calorimeters used to measure the energy resulted in IEEE1584 understating the energy as seen by the body by a factor of three compared to a horizontal parallel three phase bus configuration.

As well as being more representative of real life switchboard and MCC scenarios the horizontal arrangement directs (by Lenz's Law) the arc products (plasma cloud, molten metal etc.) directly at the test dummy and sensors. The opposing electrode configuration utilised in IEEE1584 predominantly exposes the test dummy and sensors to the radiant heat from the arc. The picture below combines figures from NENS 09 to illustrate the difference between the energy received to the end and to the side of the electrodes.

CONFIRM THE RESEARCH BY OTHERS



The test results further confirm the research by others that the plasma cloud from horizontal conductor arrangement employed in switchgear increases the incident energy that the victim is exposed to. The resultant energy from the tests is a factor of arc current, duration, distance and direction.

In addition the geometry of the equipment, the shape and size of people, the position of their limbs and bulk all play a role in any potential injuries. Predicting the energy from an arc fault in many ways is like cutting the end of a fire hose off and trying to predict how wet you will get. With that in mind, the recommendation is that the predicted incident energy should be used as just one of the inputs into your arc hazard risk assessment processes that will be discussed later.

For those implementing, or considering the implementation of an electrical workers PPE policy, NENS 09 is a comprehensive guide to the selection of electrical workers' PPE covering the base level of PPE, undergarments, fabric, weave, garment construction, and garment design. Also included are sections on protection for the head, hands and feet.

GET OUT OF COTTON

The single most important take home message from NENS 09 is to get out of cotton as your electricians everyday clothing and wear a minimum 4cal/cm^2 arc rated PPE on the arms legs and torso, with higher levels of PPE for higher risk tasks or higher risk equipment.

The minimum rating is important to note. The tests revealed lots of information regarding the effects of an arc fault on a wide range of arc rated and non-arc rated PPE, and while the realised incident energy was measured at levels three times higher than predicted by IEEE1584, the clothing also performed better than expected.

LATEST VERSION OF NFPA70E

Unfortunately the driver for the tests was identifying the PPE required for the utility and while the results were worthy of a PhD, the process has not completed the loop by developing an associated PPE testing standard. Like AS4836 and NFPA70E, NENS 09 still require people to perform an arc flash hazard assessment help to identify and implement controls to reduce the likelihood and severity of an arc incident. This is where the latest version of NFPA70E provides the end user with some extra assistance.

NFPA70E 2015

Earlier versions of the American arc rated suite of standards resulted in thousands of electricians around the world moving away from plain cotton or worse and into arc rated PPE. With arc rated PPE developing quickly to match the standards the focus tended to fall on PPE to manage the hazard. Electrical consultants, myself included, have been asked to perform an arc flash hazard analysis of the installation and provide the labels for each panel so that the electricians can wear the required level of PPE as required by the standard and the analysis. Fortunately, the latest version of NFPA70E focuses more attention on utilising the hierarchy of controls to eliminate or reduce the potential impact of the hazards.

The standard includes a task and equipment based table to enable users to identify which task requires PPE and what level of PPE is required. The tables have limitations on fault level, voltage, and clearing times that require some level of engineering to establish. The clearing time restrictions generally rule out the use of the tables for at least some of the equipment onsite. Previously the standard allowed both techniques to be utilised on a given installation. The new standard does not allow a mix of the table and the calculation methods.

INFORMATION ON THE IMPACT OF DOORS

The standard also now provides much clearer information on the impact of doors on metal clad switchgear and the available incident energy. Previously having a door closed did not enable you to reduce

Capturing the effect of an Arc Fault on an arc rated work shirt. Notice the droplets of copper travelling in all directions. The electromagnetic forces act to effectively drive the plasma from the ends of the bus bars (left hand bottom edge of image) towards the arc test dummy. The resulting high temperature plasma cloud completely envelopes the dummy. Note the button travelling past the dummies chin.

the required PPE for the prospective incident energy inside the unit. The end result was that people were suiting up to complete operating tasks on closed metal clad equipment which had been built and maintained to standards designed to protect the operator. The standard now states that normal operation of equipment is permissible if all of the following conditions are satisfied in accordance with the relative codes, standards and manufacturers recommendations:

- The equipment is properly installed.
- The equipment is properly maintained.
- The equipment doors are closed and secured.
- All equipment covers are in pace and secured.
- There is no evidence of impending failure.

When doors are required to be opened and closed for normal operation, the standards technical committee advises that the door is not sufficient protection. Such operations could include racking in and out circuit breakers. If your equipment meets all of the above criteria then normal operating of the equipment is permissible without any arc rated PPE. For electricians who are required to open the door for proving de-energised, test before you touch, or other testing and fault finding then depending on your risk assessment arc rated PPE may be required.

There is of course much more information with respect to arc hazards contained in the standard and its informative annexes. The electrical hazards and controls described in NFPA 70E are not limited to arcing fault hazards and only some of the changes in the latest revision are touched on above. When used in combination with AS4836, NFPA 70E helps to provide more detail to assist companies to complete their hazard risk assessments and further develop their safe working practices.

WHAT DO WE NEED TO DO?

With the release of ENA NENS 09 Australia finally has a guideline outlining Arc Rated PPE for everyday use by electrical workers. The minimum level of 4 Cal/cm^2 is at the low end of the available

garments ratings, meaning there are numerous fabric options available for companies to choose from. NFPA 70E previously led companies towards a minimum 8 Cal/cm^2 clothing for everyday wear. This resulted in some of the fabric manufacturers developing their lowest weight options to achieve the higher rating resulting in garments that are slightly warmer to wear than the current cotton drill garments required by most mining, heavy industry, construction and utility companies. The marginal increase in weight and warmth of the clothing is the major reason for pushback from Australian electricians.

The results of all of the testing in Australia and overseas are undeniable. When faced with even low level arc hazards cotton clothing can catch alight. When it does the results can be devastating. The initial burns form the arc incident are compounded by the continued burning of the clothes increasing the severity and surface area of the burns. This reduces the likelihood of survival and increasing the pain and length of any form of recovery. In short the cotton PPE increases the likelihood of serious injury of death when compared to arc rated garments.

LOW VOLTAGE MORE DANGEROUS THAN HIGH VOLTAGE

With respect to arc hazards low voltage is almost always more dangerous than high voltage. The high prospective fault levels and lengthy fault clearing times can combine to produce dangerously high prospective incident energy levels. The high frequency of interaction with low voltage equipment and at times little to no maintenance also means that you are more likely to have an incident. As a result of incidents many Australian companies including the big miners implemented the blanket use of Arc Rated flash suits and hood for all high voltage operating work. While a step in the right direction, it worked to propagate the myth that low voltage was safer.

Across the country electricians are currently suiting up to perform High Voltage operating work and taking the suit and hood off before walking into the room next door to work on LV equipment, often with more than double the prospective incident energy. The next edition of Industrial Electrix will include case studies highlighting the elevated incident energy levels on low voltage systems for a large ore handling facility and for a smaller distribution transformer fed factory.

The cotton knit polo is still burning on the front and back many seconds after the fault has been cleared. Notice the bubbles and charring on the fibreglass arc test dummy from where the cotton has burned in.

PPE is the least favourable and lowest form of hazard control, but it should not place the worker at greater risk of serious injury or worse. From Nens 09 and generally speaking the minimum PPE required by an electrician until a safe state can be established and verified via test before you touch is:

- Arc Rated Long Sleeve Shirt buttoned at the wrist
- Arc Rated Long Pants
- Arc Rated Face Shield with chin return
- Leather gloves, or voltage rated gloves with leather outers
- Safety Glasses
- Leather Safety Boots

Other controls that eliminate the need for tasks on energised equipment, reduce the fault levels and/or protection operating times for equipment and the required procedural changes to improve the work practices are also required and will be included in next issue's case studies.

Effect of Arc Fault on cotton Knit polo. The shirt is blown open by the fault, ignites and continues to burn long after the arc is extinguished. Even the back of the shirt ignites impacting a large section of the torso and head.

All photos are printed with the permission and assistance of AUSGRID. Arc flash images captured by MACS Image.

ABOUT THE AUTHOR

Brett Cleaves is the founding director of Engineering Safety and has over 20 years engineering experience in heavy industry and electrical utilities including 8 years in Arc Flash hazard analysis and controls.

For contact information refer to www.engineeringsafety.com.au