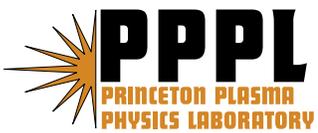

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Electrical Safety and Arc Flash Protection

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Abstract—Over the past four years, the Electrical Safety Program at PPPL has evolved in addressing changing regulatory requirements and lessons learned from accident events, particularly in regards to arc flash hazards and implementing NFPA 70E requirements. This presentation will discuss PPPL's approaches to the areas of electrical hazards evaluation, both shock and arc flash; engineered solutions for hazards mitigation such as remote racking of medium voltage breakers, operational changes for hazards avoidance, targeted personnel training and hazard appropriate personal protective equipment. Practical solutions for nominal voltage identification and zero voltage checks for lockout/tagout will also be covered. Finally, we will review the value of a comprehensive electrical drawing program, employee attitudes expressed as a personal safety work ethic, integrated safety management, and sustained management support for continuous safety improvement.

Keywords-component; safety; electrical; arc flash.

I. INTRODUCTION

Since its adoption by PPPL in 2001, NFPA 70E [1] has continued to promote evolutionary changes to our electrical safety program and equipment modifications to limit worker exposure to arc flash hazards. This paper will review elements of PPPL's Electrical Safety Program, including personnel training, hazards assessment, Laboratory policy, safety related work practices, lessons learned and management support for the program, and discuss their evolution and contributions to the safety culture.

II. THE ELEMENTS

A. Training

A significant aspect of NFPA 70E is the requirement for personnel training and qualification. The standard anticipates broad and specific training including roles and responsibilities, qualified personnel skills, awareness and self-discipline, job briefings and working on or near. Approach distances, Lockout/Tagout (LOTO), personal protective equipment (PPE) and proper use of tools and test equipment are also included. Though reviewed in the 70E training, LOTO at PPPL is given as a stand alone course since it covers more than electrical work.

PPPL's first NFPA 70E training course, Electric Utilization Training (EUT), included not only the requirements from NFPA 70E 2000 but also relevant chapters from the OSHA standards. The training was 16 hours of classroom lecture,

videos and demonstration and was required for anyone, employees and subcontractors, working on or near, even where arc flash hazards were minimal. From working with the standard and wrestling with its' implementation, the training has evolved into a 4 tier approach recently adopted and now being implemented. Everyone working at PPPL takes General Employee Training and it explains that they are not qualified to work on electrical equipment without further training. Basic Electrical Safety is our qualification training for personnel (including subcontractors) working on or near electrical equipment with limited arc flash hazards; bench technicians, electricians, graduate students, and physicists. Electric Utilization Training is derived from the original and is for power professionals working on three phase low and medium power equipment where arc flash hazards must be considered and dealt with. The last level is High Voltage training, given in conjunction with the local utility. This is for personnel working with high voltage overhead lines and equipment; a very small cadre of PPPL employees and subcontractors. As an aside, we also include approach distance training to outdoor aerial lift and hoisting & rigging training.

B. Hazards Assessments

Our approach to hazard assessment has been primarily by the book with a few notable exceptions. Qualitative assessments of those tasks with potential for significant arc flash exposure were followed up with quantitative analyses using 70E methodologies. These then translated into equipment replacements, redesigns or operational restrictions to limit worker exposure to the hazard. Equipment affected in this way include 138kV motorized switches (replacement), 480V network protector modifications (redesign) and 480V DB-type breakers (racking restrictions).

For operational procedures (switching orders) we include hazards analyses as part of the procedure, including voltage class (shock hazard), arc flash hazard category and necessary PPE, step by step in the switching order.

C. Clear Policies

Out of the early EUT classes, PPPL established clear policies with precise language that is used at all levels of electrical safety training.

'No one shall work on energized circuits' and 'Only qualified people shall perform troubleshooting and voltage testing on energized equipment'. Work here is defined as making connections, installing or removing components ,

wiring or components. Troubleshooting and voltage testing, where de-energizing is impractical, is allowed, though we encourage connecting meters and such de-energized as a safety related work practice. Qualified means not only Laboratory employees but visitors, subcontractors and students as well.

D. Engineered Solutions

As mentioned above, we have investigated and implemented engineered solutions to limit workers' exposure to arc flash hazards by modifying equipment. This has been particularly true for high voltage (138KV switches) and high current (480V network protectors) situations. Full time panel voltage indicators have also been implemented at the 480V and 120/208V level to provide loss of voltage indication prior to hands on troubleshooting.

E. Hazard Avoidance

This element is also called Safety Related Work Practices. While the Laboratory's policies in regard to electrical and arc flash safety are clear (see above), how people troubleshoot or diagnose energized equipment can further limit exposure to the hazards. For example, de-energizing a circuit before hooking up meters. These practices relate to specific equipment and circumstances at PPPL. Other operational practices covered:

- Racking medium voltage breakers.
- Inserting and removing Motor Control Center (MCC) buckets.
- Operating 480V Network Protectors

F. Personal Protective Equipment

Since the incorporation of NFPA 70E into our electrical safety program in 2001, we have had a Laboratory-provided, fire retardant (FR) clothing allocation program for electric power professionals. This program provides FR clothing for daily (NFPA 70E hazard category 1, minimum arc rating 4 cal/cm²) with layering (coveralls, arc flash suit) up to hazard category 4. Arc rated face shields, safety glasses, voltage rated gloves and tools, and hard hats are also provided. Comfort is a key criteria for the everyday wear, since if it isn't comfortable, the employees won't wear them, defeating the purpose of providing them.

G. Nominal Voltage Identification

PPPL uses an alphabetic code to label and identify the voltage class of electric distribution equipment:

- X = 138kV
- V = 26kV
- S = 13.8kV
- Q = 4161V
- P = 480V
- L = 120/208V

So a 138kV to 13.8kV transformer would be labeled XST. This nomenclature and labeling meets the 70E requirements for determining the nominal voltage of equipment.

H. Drawing Program

The value of this aspect of electrical safety is often overlooked, and when combined with consistent labeling (above) can make significant contributions to reducing lockout/tagout errors. It is the first step in any effective lockout/tagout program (identify all sources of power to the equipment being de-energized). PPPL dedicates one third of a draftspersons time to maintaining and updating drawings and panel schedules (about 1000 drawings).

I. Zero Voltage Checks (below 600V)

Between the 2000 and the 2004 editions of NFPA 70E, the requirements for zero voltage check became more stringent. The 2000 edition said "...test each phase conductor or circuit part to verify they are de-energized." This would permit using an appropriately rated non-contact voltage detector for zero voltage checks. In the 2004 edition, an extra sentence is added: "Test each phase conductor or circuit part both phase-to-phase and phase-to-ground." PPPL now uses meters that can perform both functions, using the non-contact feature to assure that we have de-energized the right component, and meter probes to meet the 2004 edition requirements.

J. Personal Safety Work Ethic

All of our electrical safety training emphasizes this appeal to self-preservation. We discuss internal and outside accidents and near miss episodes to reinforce safety training. We discuss accidents, injuries and fatalities in terms of impacts on employees, families and quality of life. And we promote a mature, skeptical, self-disciplined approach to electrical work. This is the 'high touch' aspect of electrical safety.

K. Integrated Safety Management (ISM)

For those of you not associated with the DOE national laboratories, this may be new. ISM utilizes 7 guiding principles and 5 core functions as a framework for performing activities in a safe manner. There is a clear correspondence between the requirements of 70E and the guiding principles and core functions of ISM.

L. Management Support

This element is essential to any successful safety program, and PPPL has enjoyed support, both moral and monetary, from the Directors Office on down, for the arc flash and electrical safety programs. From the Director, R. Goldston emphasizing "Safely, Safely, Safely!" in his state-of-the-Laboratory addresses to funding for equipment and clothes, to sponsoring the annual all-day safety forum, to Department heads reviewing safety training, PPPL management has demonstrated a consistent, unwavering commitment to the safety of its employees.

III. SUMMARY

There is no short cut to electrical safety. It takes commitment from all levels of an organization to the broad array of elements (some discussed above) on a day-to-day basis, to have an effective and comprehensive arc flash and electrical safety program.

ACKNOWLEDGMENTS

I would like to thank Dave O'Neill (PPPL, retired), for his vision and tenacity in laying the foundations of our arc flash electrical safety program and his mentoring of so many (including the author).

REFERENCES

- [1] NFPA 70E, Standard for Electrical Safety in the Workplace, 2004 edition, National Fire Protection Association

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