AC 2008-304: ARC FLASH ANALYSIS AT THE UNIVERSITY OF MAINE

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Incorporating Arc Fault / Flash Analysis into Undergraduate Curriculum

Abstract

Arc Faults have been identified as an area of concern to industry since the early 1980s. More recently, the Occupational Safety and Health Administration (OSHA) and the National Fire Protection Association (NFPA) have revised codes stipulating that arc fault capability must be considered when doing electrical work on any circuit greater than 50V. This work includes taking voltage measurements to verify that circuits are deenergized. Many organizations require their employees working on electrical systems to wear flash suits. These suits can cost over $700.

Traditionally, power systems labs at the author's University use Hampden electrical panels to provide electric power. These panels provide a flexible method to deliver power for various experiments. The panels utilized industrial breakers and connection methods. OSHA and NFPA codes require proper personal protective equipment. However, using flash suits is not practical in a typical lab environment. This paper will discuss the methods to address arc flash in the power lab as well as how the arc flash analysis was incorporated into the class

Introduction

The author teaches several courses in electric machines and power systems. These courses have a lab component to provide students the opportunity to interact with the equipment discussed in lecture. The focus of the Electrical Engineering Technology program the author is a faculty member off is on applications. As a result, the EET program commits to offering a learning environment where equipment students are likely to encounter in industry is utilized. As a result, the labs are outfitted with the following industrial equipment:

- Resistive load bank adjustable in 72 steps.
- Reactive load bank (capacitive) in 12 steps.
- DC machine driven via a variable speed drive or synchronous or induction motor.
- Synchronous machine driven by variable speed drive or DC motor.
- Induction machine driven by variable speed drive or DC motor.
- Adjustable DC power supply from 0 to 500Vdc.
- Three phase 480Vac, wye connected supply via nine section Motor Control Center (MCC)
- Three phase 208Vac, wye connected supply.
- Single phase 120/240Vac.
- Supply and patch panels and cables.
- Computers with Pentium processor and flap panel display.
- Various measurement devices including 600V multimeters and clamp-on power meters.

The variety of the industrial equipment allows for many experiments. Unfortunately, the lab was not being fully utilized in recent years due to concerns regarding lab safety. In particular, arc fault or arc flash potential created concerns that the student safety could not be assured.

The EET program faculty are confident that experiments can be performed without student exposure to electrical shock hazards. This is accomplished via the following:

- Students are required to review a detailed lab manual that describes overall safety features. Students are not permitted in the lab without signing a form indicating they have read and understand the lab manual.
- A detailed preliminary lab is performed where lab equipment is detailed including connections and safety protocols.
- Students are required to remove all jewelry and to secure any loose clothing or hair.
- A student lab assistant is utilized during the lab to support the lab instructor.
- Students are not permitted to energize any circuits without prior examination of the circuits by the lab instructor or assistant.

Even with all these precautions, arc flash protection cannot be assured. Basically, an arc fault occurs when equipment failure results in energy flow through the air surrounding equipment. A great example of arc flash is a lighting strike. Electrical shock isn't a great concern for arc flash. The greatest concern is for personnel burns resulting from the arc flash. When an arc flash occurs, the air very rapidly ionizes and superheats. It is not uncommon for the superheated air to approach 35,000°F. With temperatures such as these, severe burns resulting in death can occur. The burns can be exacerbated when working on electrical systems with improper clothing. An example of improper clothing is the commonly worn Polypropylene or fleece clothing. Although fleece clothing has many desirable characteristics it is not intended for use where fire potential exists. This is due to the fact that polypropylene is fabricated from fossil fuels which will readily burn when ignited and require significant effort to extinguish.

Protective Equipment

NFPA 70E, Standard for Electrical Safety in the Workplace, classifies Personal Protective Equipment (PPE) levels that protect against burns. The categories are as follows:

- Category Zero: incidental energy with limited ability to arc
- Category One: five calories per square centimeter
- Category Two: eight calories per square centimeter
- Category Three: 25 calories per square centimeter
- Category Four: 40 calories per square centimeter

The categories define the ability of the equipment to allow personnel to withstand an arc fault without sustaining significant burns for a limited period of time. In many instances, multiple layers of clothing can be used to meet the categories. The clothing is rated fire retardant. Fire retardant clothing consists of natural fibers (cotton, wool, silk, etc.) that have been treated with a fire retarder. For PPE meeting the Category Four requirements, no exposed body parts are permitted and multiple layers are utilized. A PPE meeting the Category Four requirements is shown in the following figure:

Dupont Nomex PPE Suite

If the arc flash levels are unknown, it is conservative to assume Category Four PPE levels. Requiring students to wear equipment meeting Category Four requirements would ensure safety in the lab. However, the clothing is bulky and working in a lab environment is not tenable.

The only other option is to accurately determine the arc flash levels at the end user equipment and specify lower class PPE if plausible. The arc fault analysis can be accomplished with students equipped with the proper information. To enhance student learning, the arc fault analysis is incorporated into the classroom.

Arc Fault Analysis

The arc fault analysis is performed in accordance with either of two industry standards. NFPA 70E has a methodology for calculating arc fault energy levels. In addition, IEEE 1584 has a different methodology for the calculations. Students are presented with the different approaches and encouraged to evaluate the differences between the two. Some sample calculations are performed in each method during class time albeit at a highly reduced level from what a typical study would consist of.

For the lab, the faculty determined that it is most likely that students will be performing arc flash analysis with industry used software. As a result, the students were trained on data entry and evaluation for arc flash analysis software. Either the NFPA or IEEE methodology requires the same basic data and data entry. This process will be described in the following paragraphs.

The preliminary step to performing an arc fault analysis is to obtain software with the capability to determine the arc fault levels. Although this can be accomplished by hand, it is extremely time consuming and difficult. This is primarily due to the effort required to determine energy let through levels based on upstream protective device settings. There are many software programs including Power Tools for Windows, Easy Power, and ETAP to name a few. The lab instructor was most familiar with Power Tools for Windows and determined that would be the easiest software to use. Power Tools for Windows is a piece of software developed by SKM Systems Analysis, Inc. SKM has a educational program that provides free use of the software for educational use at Universities. The software has a limited number of buses so care must be used when determining what information truly necessary to enter into the software. Items such as down stream devices and loads are not required for the study.

The next step is to determine the campus electrical power distribution system layout. This is necessary to determine how power is being supplied to the lab. The power supply for the power lab is the only source of the arc fault energy. The primary source for arc flash energy is the utility connection. Obtaining the available fault current or %Z values is required for an accurate arc flash analysis. Student interaction with the local utility is encouraged to determine the steps necessary to gather data. Most utilities have a protection and coordination department that is responsible for calculating fault current levels at all locations on their system. It is possible to assume that the utility is capable of providing infinite energy but this results in overly conservative calculation results and potentially higher class PPE.

Cables, transformers, and protective devices between the lab and the utility connection limit the arc fault energy. The cables and transformers limit the arc fault energy due to the fact that they are an impedance and oppose energy flow (current).

In addition to the impedance data, it is necessary to obtain protective device settings. The most important data to enter is the protective device settings. Protective devices include all breakers, switches, fuses, contactors, etc. that are utilized to interrupt fault currents. When a fault occurs, it typically registers as a current in excess of normal values. Properly setting the protective devices limits the arc fault energy. This is accomplished by the protective devices interrupting the energy flow when their settings are exceeded. The campus distribution system, including the protective device settings, is entered into the software by the students.

The remaining step in the arc fault analysis is to run the software to determine the arc fault levels. The software indicates the levels at each piece of equipment. Labels are then generated indicating the required PPE for each piece of equipment.

Once the required Categories are determined, PPE was obtained for student use. The arc fault levels at the University only required Category Zero equipment. This resulted in requiring all students to wear only natural fiber clothing. Fire retardant lab coats and hard hats with face shields are also available.

Conclusion

The EET program where the Author teaches utilizes industrial equipment to enhance student learning. The equipment was not being fully utilized due to concerns resulting from arc faults. Having students perform arc faults as part of the class enhances the student learning and gives students an appreciation of the energy levels available at the equipment. The equipment is now being fully utilized by the students.

References

1. NFPA 70E, Standard for Electrical Safety in the Workplace
2. IEEE 1584, Guide for Performing Arc-Flash Hazard Calculations
3. OSHA 29 CFR. Part 1910, Regulation for In-Service Maintenance and Electrical Testing of Live-Line Tools
4. www.skm.com
5. http://www2.dupont.com/Nomex/en_US/