Electrical Safety and the Conflict with a Motors Course

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Abstract

As a professor responsible for teaching the Electrical Engineering Technology courses and developing curriculum for the EET program, it is has become evident that there exists a conflict between laboratory experiences traditionally taught and the Arc Flash requirements of NFPA 70E. This paper discusses the development of lab experiences that abide by the limitations of the NFPA requirements while continuing the principles of labs used prior to the implementation of this standard.

The discussion will include the argument as to why the need exists to re-visit labs using over 50 VAC equipment and how to effectively convey principles of working with higher voltage while effectively unable to have these voltages available in the teaching lab.

Lab experiences in the newly developed less-than 50 V environment will be examined. The discussion will also include lab experiences that can be accomplished using simulation. While the lab experiences of real motors and other devices is favored, it is expected that there will be fewer schools embracing labs employing electrical equipment including motors since the Arc-Flash rules have been codified. This course or any course using voltage over 50 VAC should take a hard second look at the reasons for change while not giving up on real lab experiences.

A new look at the entire course has occurred with this abstract. Previously, the course's focus was entirely on motor and transformer technology. The course has been re-constructed to encompass both the traditional motors course as well as an introduction to a traditional power course. The power course encompasses topics in transmission lines, underground cables, short-circuit current calculations, calculations of networks of devices, and protective devices' coordination.

While development of the course at first focused on the Arc-Flash rules and changes in laboratory experiences, changes in this course continue along a number of fronts including text selection, laboratory experiences and course delivery.

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Introduction

Coursework many times is developed out of a tragedy and this is one. The tragedy was the death of a fellow professor in the EET program – Dr. Ahmad Farhoud. His sickness and eventual passing was the cause of much concern for the program and the entire department as others shifted over to "help out" with the courses for Ahmad.

Course Development

One of the courses taught by Prof. Farhoud was the course commonly referenced as the motors course – EET 4350. The course name and description includes more than simply motors and is given below. This course is taught twice each year – in Fall semester during the days and in Spring during the evenings. The course is a 4-hour course with 3 hours of lecture and a one credit two-hour lab. The course had been taught in the same format for at least 20 years with Ahmad inheriting the course from a prior EET professor about 14 years ago at the time of that professor's retirement.

The course description follows:

EET 4350 – Electric Power Systems

This course constitute a study of AC/DC machines, including transformers, power transmission and the regulation governing them as specified by the industry and the National Electric Code. It covers the construction, operation, selection and control selection DC/AC generators and motors. This course also enhances the student's lab experience by connecting motors and generator in the lab and analyzing test results.

The Electric Power Systems course was taught by a part-time instructor during the year of Ahmad's illness. While this instructor was experienced in the subject material, it was determined that the course needed a full-time professor with teaching experience in the subject to take responsibility for the course and possibly take the course on as a regular teaching assignment.

A first attempt to find a more permanent solution was to discuss the course with two professors from the Electrical Engineering Department. At the University of Toledo, the Engineering Technology Department is part of the College of Engineering and share a common space in the Nitchke/North Engineering Complex. Either would have been potential instructors for the course since they were both recently retired. Their interest was genuine. But, ultimately both declined to take on the task. They both, however, recommended a change to a new text – Principles of Electric Machines and Power Electronics by P. C. Sen (Wiley). The prior text was Rotating Electric Machinery and Transformers by Richardson and Caisse (Prentice Hall). The text was changed. This text change was only partially accepted by the students. Problem sets tended to be very difficult and students tended to give up before completing even the easiest ones.

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With availability of part-time qualified instructors at a premium, it was decided that the EET professor was the choice to teach the course starting Fall 2013. He had not taught the course before. He had taken the EE Motors course as an undergraduate successfully as an EE student. The lab for that course was a one-hour course separate from the class-room course and he had been 'excused' from taking it (the result of a sympathetic advisor). He did have 15 years of industrial experience before coming to the university and had kept active in the intervening years with motor technology. He was not, however, prepared to teach the course and the start of the fall semester was less than a week away.

Lab Development

In Fall 2013, the instructor had tried to track down the labs for the course. These labs were reportedly at a bookstore on campus so he took a walk over to the bookstore to pick up a set. On the way back, he stopped at the Safety Building to discuss the safety of the laboratory since he had some interest in the possibility that the NFPA 70E 2013 Standard was not being enforced. The safety personnel were in their offices that day and questions posed concerning the safety of the laboratory equipment was met with a resounding 'no way'. The labs taught in the existing format with voltages in excess of 50 VAC were not going to happen. Excerpts from NFPA 70E 2013 are included in Appendix 1.

The lab equipment under consideration was the Hamden equipment. It was old but efficient. The labs were printed and ready to go. However, if anyone tried to use them and a student get hurt, both the university and the instructor would be liable.

The next step was to regroup and begin to write labs from scratch with equipment less than 50 volts. The result was to provide the lab experiences with low-voltage equipment as well as some simulation labs if they could be developed. The decision was made at that time to write new labs.

After making the decision to change, there was still some curiosity as to the validity of the decision to change the labs. A number of fellow practicing electrical engineers were queried and all agreed that the Hamden equipment was not safe with regard to the present OSHA requirements. The question was also posed to the electrical community on a prominent electrical internet forum. The answer was the same. The need to be safe was paramount even though the Arc-Flash rules were for industry and not educational institutions.

The question was also posed to a number of fellow professors. No one in this university would discuss the question of suspending labs for Arc-Flash, a disappointing but not unexpected occurrence. However, at a forum of heads of departments (sitting at a dinner table during a recruiting visit), several opinions were voiced and none disagreed that the decision to abandon the Hamdan equipment and stay at less-than 50 volt labs was a mistake. Their conclusion was that most schools had abandoned the lab component of the course entirely. This was a course that EET programs should not be willing to do since EET is a hands-on curriculum and the desire for hands-on labs has been a distinctive of the program. Other comments were that their schools had abandoned the hardware and moved to a simulation-only lab experience with computer

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output. This also was not an acceptable course of action, because the purpose of education is to help the students to prepare for the proper actions when facing the problems in the real life.

Results

After a year, the book was deemed too difficult and a subsequent change was made. The test chosen was Electric Machines – Principles, Applications, and Control Schematics by Dino Zorbas. The text was used in Fall 2014 with better results. The text has both exercises scattered in the text as well as problems at the end of the chapter. A combination of the both exercise and end-of-chapter problems seems to be an acceptable expectation for most EET students. The course was taught in Spring 2015 via a part-time instructor. Results from this class were not acceptable due to lack of some theoretical concepts with the instructor.

The course was also still too difficult for most students and a further look for a text occurred. Again, the complaints were that too many students avoided the homework due to difficult problem sets.

Subsequently, a different approach to the text occurred for Fall 2015. Two texts were used:

Schaum's Outline Of Electric Machines & Electromechanics, 2nd Ed,S. A. Nasar and:

Schaum's Outline Of Electrical Power Systems, 1st Ed, S. A. Nasar

A different tact was also taken concerning expectations and grades. The course now has a quiz each week with homework somewhat required but answers were given in advance. The Schaum’s books have a number of worked problems and can be a good source of homework. The students were required to only have a small index card with them for the quizzes so they had to organize the problems for the week in a small area and be ready to solve one or two problems from the list.

With the second text, Outline of Electrical Power Systems, additional topics could be explored outside of motors. This gave a greater breadth to the course although the topics were treated in a survey manner. They included topics in transmission lines, fault calculations and system admittance. The course moved very fast in the later weeks but was satisfying in that the students were introduced to a number of topics they would not have had previously.

In the Spring 2016, this course is taught by another part-time instructor, a young Engineer In Training working at a local engineering consulting firm. He was a successful student graduated from EET department and later obtained his MSEE degree in 2014. He is expected to use his education and working experience to help the students to understand the course’s material, bring real-life problems to the classroom to inspire students thinking practically.

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Topics presently include:

Maxwell's Equations
RMS derivation
AC steady state
AC power
Magnetic equations
Solenoids
Transformers
Motor circuits
AC motor fundamentals
DC motor fundamentals
Servo and stepper motors
One-line and power distribution (Introduction)
Power transmission (Introduction)
Short-Circuit Computing, Arc Flash Boundary and Incident Energy Calculation
Protection Devices' Coordination (Introduction)

The labs follow the text usually by about a week or two and generally complement the text. The first two labs were introduced to make sure the student knew the steps in wiring a traditional motor starter without hooking it to power as well as the drawings that show the motor – the one-line and the three-line drawings. It was explained that the one-line drawing serves as the drawing of record if an OSHA official inspects the facility. The fault currents should be placed on the one-line at various points to show the distribution of fault current in the facility. Some problems in the second Schaum's book offered calculation results to supplement the one-line diagram's fault current listings.

Students will also have the chance to be exposed to three useful topics in the power system in addition to the Electric Motors, these three introduction topics will help them to obtain basic power engineering knowledges they may face in the future.

Discussion with Students

The students who took the course in the year between the changes that have been outlined here and the end of Ahmad's active tenure had many comments that helped to shape the present course. One student encouraged the use of safety equipment in the lab using the Hamden equipment. This led to the effort to stop by the safety building which was really a request for use of safety equipment including glasses. This comment was timely in that even the students knew that there were problems with their exposure to 230 VAC in an open environment even though the university had tended to ignore the problem.

The labs are presently being reviewed to provide a better over-all experience while maintaining integrity of the lab experiences. There are some complaints pertaining to the degree of difficulty of some of the labs in which students are unable to adequately complete the labs in a timely manner. The lab equipment provided was bought in Fall 2013 and used by students in that semester. Equipment is being evaluated to upgrade and fix the items needing replacement.

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What happened to the Hamden Lab? The EE classes continue to use it and upgrade to newer equipment still above the 50V threshold. Teaching assistants are assigned to teach the labs and students continue to learn on this equipment.

The use of videos in this course will be continued and enhanced as the course moves forward.

The program also received commitment for some VFD motor controllers from a reliable vendor recently. The use of small 3-phase VFD motors and motor controls is a plus going forward since the current and voltage can be displayed in the display window of the drives. Going forward, the course will continue to provide the less-than-50 volt labs but carefully move to include state-of-the-art motor controls with protection for the student.

Summary

The Motors course needed to be changed but the manner in which the change came about was not expected or desired. The sickness and passing of one of the best professors in EET was not planned nor was the ensuing division of his courses among other faculty a planned occurrence. Events unfolded, however, and courses were ultimately re-assigned. The Motors course was one of these courses. The attempt by the authors to examine this course led to a number of changes. First, the book was changed. Then the labs were changed.

This may be considered by some as ‘just soldiering on’. However, there needs to be an evaluation as to how any course is taught based on the changes of the profession. This is a responsibility of the professor. The needed changes were implemented even while there has been continuing effort to evaluate whether the decision to abandon the Hamden equipment was correct. The professor should give primary consideration to how best to give students experiences similar to those of prior years but that are considered safe by today’s standards.

Hopefully, there will be discussions about the merits of the changes of the Motors course as they pertain to other universities and the need for true hands-on lab experiences coupled with the theoretical concepts they demonstrate. Nothing would have pleased Ahmad more.

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Appendix 1

NFPA 70E

(A) Covered. This standard addresses electrical safety-related work practices for employee workplaces that are necessary for the practical safeguarding of employees relative to the hazards associated with electrical energy during activities such as the installation, inspection, operation, maintenance, and demolition of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways. This standard also includes safety work practices for employees performing other work activities that can expose them to electrical hazards as well as safe work practices for the following:

(1) installation of conductors and equipment that connect to the supply of electricity

(2) installations used by the electric utility, such as office buildings, , warehouses, garages, machine shops, and recreational building that are not an integral part of a generating plant, substation, or control center

Article 130 Work Involving Electrical Hazards

(A) Energized Work

(1) **Greater Hazard**. Energized work shall be permitted where the employer can demonstrate that de-energizing introduces additional hazards or increased risk.

(2) **Infeasibility**. Energized work shall be permitted where the employer can demonstrate that the task to be performed is infeasible in a de-energized state due to equipment design or operational limitations.

(3) **Less Than 50 Volts**. Energized electrical conductors and circuit parts that operate at less than 50 volts shall not be required to be de-energized where the capacity of the source and any overcurrent protection between the energy source and the worker are considered and it is determined that there will be no increased exposure to electrical burns or to explosion due to electric arcs.

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