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Electrical Engineering Education In An Industrial Laboratory

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***Abstract*—This paper describes a unique electrical engineering laboratory course. This laboratory is an example of industry-university cooperation in engineering education. The organization and operation of the course is outlined and explained.**

The educational benefits derived from such cooperation between industry and the university are briefly detailed. These benefits are extended to the students, the university, the faculty, and the participating industry. This paper provides the framework and challenge to industry from which other laboratory experiences can be conceived and developed.

Introduction

MUCH criticism is leveled at engineering education for providing too little exposure to laboratory testing and to the latest in equipment and methods of testing. This is valid criticism, but in many cases it is financially impossible for a university to provide the facilities, instruments, and samples of the latest equipment developments without industrial support. In many cases, it would be financially unsound for a university to build certain laboratory facilities because of their specialized application, their limited use, and high capital investment; however, in many cases, the material would be very beneficial to those students who are interested in a particular field of specialization.

This paper describes a unique electrical engineering laboratory course in an effort to show how industry can participate in engineering education for the mutual benefit of the student and the university as well as industry. The laboratory course to which reference is made is entitled Extra High Voltage Laboratory (EHV). It was developed in the fall of 1969 for the students of the University of Missouri-Rolla, through the cooperative efforts of the A. B. Chance Company of Centralia, Mo., and the Department of Electrical Engineering of the University of Missouri-Rolla.

The EHV laboratory is of special interest to the electrical engineering power area and is a good example of a specialized laboratory. There are, however, many well-equipped laboratories which could be used in the same manner as the A. B. Chance Laboratory to provide educational opportunities in other fields of specialization. It is my opinion that other industries and universities should consider similar possibilities in other areas and possibly use the described laboratory course as an example for organizing other specialized laboratory experiences.

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Many people have asked me how the arrangements with industry were organized, what cost was involved, and what particular problems had to be overcome to establish the course. Surprisingly enough, the problems encountered in establishing the course were minimal. I must give credit to one of my colleagues, Prof. G. McPherson, who established the initial contact by telling T. Fry, Manager of Engineering for the A. B. Chance Company, that we would like to use the laboratory for our students. Mr. Fry answered McPherson's proposal a short time later by saying that if a reasonable course could be organized, he would be willing to permit students to run tests in the laboratory. This suggestion was passed on to me, and the course described herein was developed.

The cost to the University of Missouri-Rolla for the operation of the course involves the expense of driving two automobiles a distance of 240 mi for four round trips each semester, or approximately $96. The cost to the A. B. Chance Company includes laboratory time and personnel time, which together is estimated to cost nearly $3500 per semester. The only problem of any significance in operating the course is the arrangement of the students schedules for the all-day trip, which is rather long and requires two faculty members to drive the University cars.

To date, 36 students have taken the course. It was originally limited to eight students per semester because of the two-car limit; however, the demand has been so intense that for the last two semesters, ten students have been enrolled and every semester an equal number of students have requested the course but have been denied the opportunity to participate.

Educational Benefits

The operation of the laboratory has proven to be of benefit to the students, the University, the faculty, and the A. B. Chance Company. An evaluation of the benefits derived from this type of industry–university cooperation is enlightening.

The student benefits educationally by being able to test equipment which represents the latest in industrial developments. He is also able to do his testing in a uniquely well-equipped laboratory, which has a professional staff of industrial engineers in attendance. Experience has shown that this type of exposure greatly enhances the student's interest and consequent learning.

Many of the students, who have taken the course, have used the experience as a plus factor for themselves in interviewing for jobs, primarily with utilities and power equipment manufacturers. The students have been able to point to a special interest in and preparation for an industrial laboratory; factors which have aided them in job placement. Almost without exception, the students have indicated that the course has provided them with one of their most significant educational experiences.

The University benefits by having available for the minimal cost of transportation a sophisticated laboratory which represents a prohibitively large capital and maintenance expense.

The faculty members are able to enrich their classroom teaching with examples and discussions drawn from experience in the laboratory. They also benefit from the professional association and discussions with the staff of the cooperating industry. A rapport between the university and the industry is an important result of the faculty and student visits.

A short-term gain for the cooperating industry is the rapport which it establishes with the university, the faculty, and the students. Long-term gains are more significant. Industry can satisfy itself that some students have had the equipment and testing exposure that it has been suggesting is desirable and needed. Furthermore, future employees of an industry are more likely to be drawn from among those students who have had prior knowledge of the industry.

Conduct of the Course

The facilities, which are provided for the course by the A. B. Chance Company in its F. Gano Chance Engineering Research Center, include mechanical, environmental, short-circuit, and high-voltage laboratories (see Fig. 1). The power source for the short-circuit laboratory is a 762 MVA short-circuit generator. The key items of equipment in the high-voltage laboratory are a 2400-kV impulse generator and cascaded 60-Hz transformers rated at 1000 kV.

The course is divided into four basic parts: 1) preparatory lecture, 2) tests at the A. B. Chance facility, 3) review of the tests, and 4) an engineering report.

The preparatory lecture is held on the Rolla campus, and the students are introduced to the theoretical aspects of the tests to be run during the following testing period at the A. B. Chance laboratory. The applicable standards are passed out to the students, and the test procedure described by the standards is discussed. Circuit diagrams for each type of test, as well as the circuits and specifications for the test equipment to be used in the experiments, are given to the students.

The day-long testing period at the A. B. Chance facility consists of two parts. The first part is a lecture in which company engineers discuss theoretical aspects and their applicability to the tests to be performed. The operation of the equipment and the practical problems encountered in performing each test are explained. Additional tests, which are applicable to the day's work

Fig. 1. University of Missouri-Rolla students preparing 50-cm spheres for 60-Hz calibration tests on high-voltage instrumentation.

but which cannot be run due to time limitations, are detailed by means of slides. The second part of the day is spent in running the tests scheduled for the visit.

Following each test period, the students meet with the professor to discuss the results of the tests. Questions about the procedure and meaning of the results are covered. The format and information required in the report are outlined. And finally, each student prepares a formal report of the test, its procedures, and the results.

Course Material

The course begins with an introduction to the American National Standards Institute (ANSI) and the National Electric Manufacturing Association (NEMA) standards, which are used as part of the text material for the course. Other material includes equipment specifications on the test equipment, equipment specifications on the devices to be placed under test, and Bureau of Standards publications. Outside reading is assigned from several IEEE articles and selected texts.

Examples of the tests made during the testing session are:

1) 60-Hz withstand tests, wet and dry, on suspension insulators and fuse cutouts;
2) impulse tests, positive and negative, on suspension insulators and fuse cutouts;
3) interrupting tests on a 15-kV fuse cutout;
4) RIV and corona measurements on fuse cutouts, line connectors, and primary terminators;
5) certification testing and operation of vehicle mounted work platforms. Each student works a 345-kV line hot from the Pitman "Hotstik" truck used;
6) calibration tests for calibrating high-voltage measurement equipment.

Conclusion

I hope that this paper will be helpful to others who are interested in establishing cooperative courses. I hope those in industry with well-equipped laboratories will read this article and give careful consideration to offering their laboratories for part-time student use. As for those in the university who know of laboratories they would like to use, I hope they will develop their ideas and present them to the management of that industry and that this article will aid them in some way in developing other laboratories. If security is a problem for an industry, a little care can overcome the problem. The power industry is very sensitive about confidential developments, but I have not had any problems with security in the described laboratory, so it can be done if the spirit of cooperation is there.

Fourier Analysis Using Coherent Light

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Abstract—**Simple lenses can be used to produce the Fourier transform of a spatial signal. Two optical experiments related to Fourier analysis are described. The first experiment measures the power spectrum of a spatial signal and displays the result directly on an oscilloscope. The second experiment measures both the convolution and the correlation of two spatial signals and again displays the result on an oscilloscope. The use of the experiments in undergraduate engineering laboratories at Oakland University is described.**

I. Introduction

FOURIER analysis and frequency-domain representations of physical systems have long played a central role in engineering. It is customary for students to study Fourier transforms by considering time signals (i.e., signals which vary with time) which are transformed to a frequency domain where the frequency has the dimensions of cycles/s or Hz. This paper describes a number of experiments which engineering students at Oakland University, Rochester, Mich., perform in connection with their study of Fourier analysis. In these experiments the student considers spatial signals (i.e., signals which vary with distance) which are transformed to a spatial frequency domain where the frequency has the dimensions of cycles/mm or lines/mm. The signal is typically recorded on photographic film where the amplitude of the signal is proportional to the amplitude of the light transmitted by the film. The signal is Fourier transformed by using a simple lens.

The experiments described in this paper are used in a junior-level core course in fields and waves. About four weeks of the course are devoted exclusively to a study of Fourier analysis. The Fourier integral and its relationship to the delta function is first introduced. This is followed by a discussion of the scaling and shifting theorems which are used to calculate the Fourier transforms of the signals used in the spectrum analysis experiments described in Section II. Convolution and correlation integrals are evaluated graphically. This graphical method is directly related to the optical measurement technique described in Section III. Using convolution methods to study the Fourier transforms of periodic functions then leads directly to Fourier series.

There are a number of advantages to studying Fourier analysis using spatial signals. In the first place the frequency domain is not simply an abstract mathematical representation but is actually a physical plane on which light is distributed in proportion to the Fourier transform of the signal. In the second place, because the signals are spatial signals rather than time signals, the limitations imposed by causality no longer exist. Thus, one can study noncausal signals and construct ideal frequency-domain filters (for example, a slit). The spectrum of nonperiodic signals such as a single pulse or only a few pulses is readily measured and even complex signals can be generated by varying the phase shift of the light through different parts of the film. Thus many of the restrictions which are inherent with time signals can be removed when dealing with spatial signals.

In Section II the method of taking Fourier transforms optically will be described and several results showing the power spectrum as a distribution of light intensity in space and recorded as a time signal on an oscilloscope will be presented. In Section III a method of displaying directly on an oscilloscope the convolution and cross correlation of two spatial signals will be demonstrated.

II. Optical Spectrum Analysis

Although the Fourier transforming property of lenses under coherent illumination has been known for a long time, it is only in recent years that it has been exploited

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