

## **A Video-Taped Laboratory in Electrical Power and Machinery**

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### **Abstract**

The development and implementation of an upper-division (junior-level) electrical power and machinery laboratory utilizing video taping of the machine operation is described. The laboratory course was developed to accommodate distance-learning students who have limited or no access to campus facilities. All students enrolled in the course have completed an associate degree in electronics or electrical engineering technology and, therefore, have completed traditional basic electronic courses taught in a traditional laboratory environment. Moreover, most of the students are working in industry as engineering technicians and have sufficient maturity to understand the practical aspects of their observations.

Unlike many of the experiments in electronic circuits where innovation is encouraged, most experiments in electrical power and machinery are highly structured because of the potential safety hazards and the potential destruction to expensive equipment. Therefore, the actual wiring diagrams are relatively simple and do not present any significant challenges to students. The major educational objectives are the measurement of performance parameters and the correlation of results with predicted theoretical models.

All of the experiments parallel those offered in the more traditional course on the campus and include numerous performance tests on dc and ac motors and generators as well as power transformers. Each video taped experiment begins by showing the instructor wiring the circuit. The student is supplied with wiring diagrams to enhance correlation with the actual wiring details. The machines are then operated by the instructor in a step-by-step fashion, and the camera zooms in on each instrument reading. The student records the data in the same fashion as if he or she were performing the test within the laboratory. The student then analyzes the data, prepares performance calculations and curves, and submits comprehensive reports to the instructor.

A comprehensive final examination testing the expected outcomes of the course has been developed and implemented. Performance studies thus far indicate that the video-taped laboratory is equally effective with the traditional laboratory. Students also indicate that they work harder and require more time than with traditional laboratories, but their overall evaluation is very positive. The recorded materials will shortly be transferred to either CD-ROM or to DVD format.

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## **I. Introduction**

Old Dominion University in Norfolk, Virginia, offers TAC of ABET accredited baccalaureate programs in Civil Engineering Technology, Electrical Engineering Technology, and Mechanical Engineering Technology. Although the entire four-year programs are offered on campus, from the very beginning in the early 70s, transfer students entering at the junior level have constituted a major portion of the student body. Students entering at the junior level are required to have an associate degree or its equivalent in the pertinent field of study. This group has always performed at a level comparable to our "natives", and many of our most outstanding graduates have entered the programs in this manner.

Around 1992, the University created the distance learning program called TELETECHNET, in which junior and senior level instruction has been provided by one-way video and two-way audio to numerous sites in the Commonwealth of Virginia and elsewhere. Due to a very high demand on the part of industry, the engineering technology programs were among the first to be offered in this manner, and the televised programs have become an integral part of the department's mission. The overall TELETECHNET initiative has grown to the point where Old Dominion University now has the largest undergraduate distance learning program in the country, and the institution has been cited by Forbes Magazine as one of the "top 20 cyber-universities" in the country.<sup>1</sup>

Lecture courses have presented no special problems other than orienting faculty toward the special preparation required for televised lectures. During the semester when a course is televised, it is normally the only section available, so full-time campus students take the course in the studio at the same time that it is being broadcast. Consistently, off-campus students perform at a level equal to or greater than that of the on-campus students. This is probably due to the higher maturity level of the off-campus students who are typically working full-time as technicians and are more serious about their education than the typical "youngsters" on campus. The students and faculty communicate using email and a toll-free number. While the students are physically "invisible" to the faculty, many faculty feel that they have more day-to-day interaction with these off-campus students than with on-campus students due to the resources available.

## **II. Laboratory Challenges**

The greatest challenge thus far has been the development and implementation of appropriate laboratory experiences for off-campus students. During the early phases when most students were within the immediate geographic region, weekend laboratory packages were developed, and are still being used to a great extent. However, as sites at greater distances became more prevalent, the need for new approaches became evident.

Around 1996, the concept of "virtually-enhanced laboratories" (VEL) became a point of serious discussion. For the purpose of this paper, a VEL will be defined as an educational endeavor in which a portion or all of a traditional laboratory course is replaced by a substitute process that can be achieved by a student at a distance. This includes computer simulation, video-taped (or

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CD-ROM) experiences, and the remote control of an on-campus device from an off-campus location. Many different approaches have been investigated over the past few years and some are still under development at this time. Several papers have been accepted for presentation at this conference dealing with various approaches in each of the engineering technology disciplines.

It should be emphasized at the outset that none of the faculty feel that VELs could ever serve as a complete replacement for traditional laboratory instruction. At the freshmen and sophomore levels and in the associate degree programs feeding Old Dominion University, traditional laboratory courses still prevail. However, by the time a student reaches the junior level, he or she should be familiar with the basic laboratory skills in the discipline. At that point, we feel that appropriate experiences can be achieved without necessarily having the student actually "touch real equipment".

Not all faculty were initially warm to the idea of VELs. As the process has evolved, however, most of these faculty have become more convinced that well designed experiences can be as effective as, and in some cases even more effective than, traditional laboratories. In fact, anyone teaching traditional laboratories is well aware that some students can get through the labs by leaning on a partner without ever experiencing the full value of the work.

### **III. The EET 365 Model**

This particular paper deals with a junior laboratory course, EET 365, *Electrical Power and Machinery Laboratory*. This course requires as a co-requisite or prerequisite the lecture course EET 360, *Electrical Power and Machinery*. The text for the course is *Electric Machines*, by Charles I. Hubert<sup>2</sup>.

The EET365, Electrical Power and Machinery Laboratory course at Old Dominion University is offered in two formats. First, the "conventional format" lab course consists of students performing twelve laboratory experiments on various AC and DC motors and generators, transformers, and an experiment introducing students to Programmable Logic Controllers. In this course, the students are provided with a laboratory manual/workbook which describes the purpose of the experiment, shows schematic diagrams of the circuit, has a step-by-step procedure for the wiring, operation, and measurements, and provides space for the recording of measured results. At the beginning of each class meeting, the instructor describes the purpose of the experiment, the types of measurements to be made and explains any special equipment that will be used (strobo-tachometer, dynamometer, power factor meter, etc.). The students then proceed to mechanically and electrically connect the equipment, adjust the operating parameters, and record the measured values. Later (after class), the students complete the experiment by making necessary calculations with the collected data, evaluating the results, formulating conclusions, and writing a laboratory report. Because of the hazardous nature of the rotating equipment and the high voltages used, students are not permitted to deviate from the prescribed experimental procedure, nor are they encouraged to "experiment" with various ways of connecting the equipment.

The second format of this course is a video taped version that is designed for the distance learning students. In this course, the students are provided with the same laboratory manual/workbook as is used in the conventional laboratory course. However, instead of the student attending the course in an on-campus laboratory environment, several VHS video tapes are provided that contain the twelve experiments. In each video experiment, the instructor describes the purpose of the experiment, the types of measurements to be made and explains any special equipment that will be used (strobe-tachometer, dynamometer, power factor meter, etc.). The instructor then wires and operates the equipment on-camera according to the schematic and experimental procedure provided in the laboratory workbook. Measurements are not made by the instructor. Instead, each time the procedure calls for a measurement to be made, the camera zooms to the instruments and the students record the appropriate data in their workbooks. After the video portion ends, the students complete the experiment in the same way as those in the conventional laboratory course; i.e., by making necessary calculations with the collected data, evaluating the results, formulating conclusions, and writing a laboratory report.

The fundamental difference between these two course formats is that in the video taped course the instructor wires and operates the equipment. Otherwise, in both types of lab course, the students use the same workbook, perform the same experiments, view the operation of the same lab equipment, and submit the same type of required report assignments. Although students in the video taped laboratory course do not obtain hands-on experience from this course, this has been judged by the faculty to be of little consequence. The reasoning for this is that 1) since this is a junior-level course, all students will have had significant hands-on laboratory experience prior to the course, 2) the laboratory procedure is highly structured (deviation from the written procedure is not allowed), and 3) there is little educational value to be gained by standing near an operating transformer, motor or generator.

The course objectives for both the on-campus and VEL class are:

- (1) Discuss the various measurements that can be made to characterize a dc machine.
- (2) Describe the measurement procedures and provide circuit schematics for open and short-circuit tests on a transformer, and show how the equivalent circuit model is obtained.
- (3) Describe the measurement procedures and provide circuit schematics for determining autotransformer properties.
- (4) Describe the procedure and provide circuit schematic for connecting and operating an alternator, including parallel operation.
- (5) Describe the procedure and provide circuit schematics for connecting and operating three-phase induction motors.
- (6) Describe the procedure and provide circuit schematics for connecting and operating single-phase induction motors.

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- (7) Describe the procedure and provide circuit schematic for connecting and operating dc generators, including series, shunt, and compound connections.
- (8) Develop the ability to specify and write programs for a typical programmable controller.
- (9) Describe the procedure and provide circuit schematic for connecting and operating dc motors, including series, shunt, and compound connections.
- (10) Describe the safety hazards associated with an electrical power and machinery laboratory and the means required to minimize the hazards.
- (11) Develop proficiency in writing laboratory reports.

#### **IV. Assessment Methods**

In order to determine if the EET 365 VEL course is comparable to the on-campus version of the course, it is necessary to evaluate students completing both types of course with respect to an identical measurement method. The evaluation method is twofold. First, an outcome assessment has been developed for the course. Since this is a laboratory course, the assessment methods available are the result of laboratory reports submitted by the students, and a formal comprehensive examination at the conclusion of the course. The goals and assessment criteria for this course are included in Appendix A of this paper. Second, both the conventional laboratory course and the video taped laboratory course are measured against the outcome assessment criteria and the results compared. Since each objective outcome will be individually measured and since the objectives are delineated by experiment subject, an additional benefit of this process will be that inherent weaknesses in any individual laboratory experiments should become apparent.

The objective outcomes are assessed using the results of graded laboratory reports and a final comprehensive examination. Laboratory report outcomes are deemed acceptable if the class being evaluated scores a minimum average of B (82.5/100) on a report. Questions and problems on the final examination will each be related to a specific assessment goal. Average scores on each question will be compiled and attributed to its respective goal. An examination result for a particular goal is deemed acceptable if the average for the class is 75 or above on a scale of 100.

#### **IV. Initial Results**

Since instituting this assessment method, the EET365 conventional laboratory course has not been offered, so no data are yet available on this course format. However, the EET365 video taped course was offered with an enrollment of eight students and, although the sample size was small, data were collected and compiled. Table 1 below lists the results.

Goal #	Laboratory Report Score	Final Examination Pertinent Question Score
1	(Experiments 1 & 2): <b>93.3</b>	<b>59.4</b>
2	(Experiment 3): <b>94.3</b>	<b>81.3</b>
3	(Experiment 4): <b>84.5</b>	<b>81.3</b>
4	(Experiment 5): <b>96.5</b>	<b>87.5</b>
5	(Experiment 6): <b>96.0</b>	<b>75.0</b>
6	(Experiment 7): <b>88.5</b>	<b>62.5</b>
7	(Experiments 8 & 10): <b>90.7</b>	<b>65.6</b>
8	(Experiment 9): <b>89.3</b>	<b>81.3</b>
9	(Experiments 11 & 12): <b>90.7</b>	<b>56.3</b>
10	N/A (Reading assignment)	<b>81.3</b>
11	Overall report average score: <b>91.8</b>	N/A

Table 1 – EET365 VEL Initial Results

Meaningful feedback is available from the data. It is apparent that further study is needed of experiments 1, 2, 7, 8, 10, 11, and 12 and their respective final examination questions (assessment goals 1, 6, 7, and 9). Although the laboratory report scores on these subjects are acceptable, the final examination scores on related questions are low. This could indicate either needed restructuring or rewording of the examination questions, or a revision of the experimental process.

Because of the need for the above data, some modification in the course grading methods are needed. Objective 11 states that students will “develop capability in writing laboratory reports”. Although this course is very writing intensive, when the reports are graded, the writing mechanics score and the technical content score are combined. In the future, these two scores will be separately recorded by the instructor so that the class can be evaluated on both writing skills and the ability to formulate and accurately present technical results.

Some students have shown overwhelming enthusiasm for the approach. One student wrote on a course evaluation that the VEL Electrical Power and Machinery Lab and the Linear Electronics Lab presented at this conference by Hackworth and Stanley<sup>3</sup> were the two most effective laboratory courses that he had ever taken.

Two points are very clear from the results obtained thus far: (1) More responsibility in the learning process is shifted to the student; i. e., each person must perform the work without the help of a partner to carry out the assignment. (2) Students indicate that the amount of time required is much greater than in a conventional laboratory. If the amount of learning is a direct function of the time involved, this would certainly suggest that the learning process can be substantial.

Collection of class performance is ongoing and will continue, so that a more detailed comparison will be made of the performance of an on-campus control group and a group taking the course in a virtual mode. Over a period of several years, more data will show if the trend indicated by the initial results continues.

## V. Summary and Conclusions

A junior-level Electrical Power and Machinery laboratory course utilizing video taped experiments has been developed at Old Dominion University for the purpose of providing instruction to distance learning students. All students enrolled in the course have completed traditional laboratory courses and most are employed as engineering technicians in industry. The use of internet resources has provided a strong supplement to enhance the communication between instructor and student.

Initial conclusions are that the effectiveness of this approach is comparable to that of a conventional laboratory environment; however, ongoing evaluation and comparisons of the two lab formats are planned.

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## Appendix A - EET 365 Electrical Power and Machinery Laboratory Goals and Assessment

**Prerequisite Skills:** A prerequisite to this course is EET 205, Circuits Laboratory, or its equivalent. A pre- or co-requisite is EET 360, Electrical Power and Machinery. Specific skills that should have been demonstrated prior to the course are the following:

1. Apply basic safety precautions in an electrical laboratory.
2. Perform preliminary estimates to ensure appropriate instruments are selected.
3. Connect correctly both dc and ac voltmeters and ammeters.

Goal #	OBJECTIVE	VALIDATION
1	Discuss the various measurements that can be made to characterize a dc machine (Exp. 1 & 2).	Record data from measurements performed on a dc machine and develop basic circuit models to characterize the machine.
2	Describe measurement procedures and provide circuit schematics for open and short-circuit tests on a transformer and show how equivalent circuit model is obtained (Exp. 3).	Record data from open and short-circuit tests and develop circuit model for a typical transformer.
3	Describe measurement procedures and provide circuit schematics for determining autotransformer properties (Exp. 4).	Record data from tests on a typical autotransformer and provide analysis leading to a determination of the operating specifications.
4	Describe procedure and provide circuit schematic for connecting and operating an alternator, including parallel operation (Exp. 5).	Record data from tests on a typical alternator and provide analysis leading to a determination of the operating specifications.
5	Describe procedure and provide circuit schematics for connecting and operating three-phase induction motors (Exp. 6).	Record data from tests on a typical three-phase induction motor and provide analysis leading to a determination of the operating specifications.
6	Describe procedure and provide circuit schematics for connecting and operating single-phase induction motors (Exp. 7).	Record data from tests on a single-phase induction motor and provide analysis leading to a determination of the operating specifications.
7	Describe procedure and provide circuit schematic for connecting and operating dc generators, including series, shunt, and compound connections (Exp. 8 & 10).	Record data from tests on typical dc generators and provide analysis leading to a determination of the operating specifications.
8	Develop ability to specify and write programs for a typical programmable controller (Exp. 9).	Write a program for a programmable controller that will perform a specific assigned task and verify by either wiring the circuit or by simulation that the program will satisfy the objective.
9	Describe procedure and provide circuit schematic for connecting and operating dc motors, including series, shunt, and compound connections (Exp. 11 & 12).	Record data from tests on a typical dc motor and provide analysis leading to a determination of the operating specifications.
10	Describe the safety hazards associated with an electrical power and machinery laboratory and the means required to minimize the hazards.	Demonstrate by passing a written test that the safety precautions and procedures are understood.
11	Develop proficiency in writing laboratory reports.	Demonstrate achievement by receiving satisfactory grades on all reports, with grading based on both technical content and writing skills.