Supportive Learning Tool for Electrical Machines Laboratory Using Video Clips

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Abstract. Electrical machines and electromechanical energy conversion serve as required course in most undergraduate programs in power engineering around the globe. Sophomore and junior students should attend both lecture and laboratory sessions to gain basic foundation in power engineering. The Department of Electrical Engineering, Faculty of Engineering, Chiang Mai University, Thailand, has made video clips for electrical machines laboratory and uploaded to YouTube. The main objectives of the video clips are to enable the students to review the laboratory session at their leisure time and to improve their laboratory skills. Upon completion, the students were pleased and found that the video clips were helpful.

1. Introduction
The Department of Electrical Engineering, Faculty of Engineering, Chiang Mai University, Thailand, offers both undergraduate and graduate programs in electrical engineering. The bachelor, master, and doctoral degrees are 4-, 2-, and 3-year programs, respectively. The bachelor degree program has around 80 students enrolled each year, while the master degree and the doctoral degree programs have 10-20 students enrolled each year. The department has 24 faculty members. The bachelor degree program comprises two fields of specialization: a) electric power and b) electronics, control, telecommunication, and information technology (ECTI). On average, three-fourth of the students have chosen electric power field. The students may register their major elective courses in the third and fourth year.

Electrical machines, also known as electromechanical energy conversion, is one of the required course of both fields of specialization. There are 2 lecture courses (3+3 credits) [1] and 1 laboratory course (1 credit) [2]. Electrical Machines I involves principles of energy conversion and DC machines. Electrical Machines II involves AC machines and performance analysis. Electrical Machines Laboratory can be taken in the second semester of the third year, after passing both lecture courses. Electrical machines can be regarded as one of the classical subjects in electrical engineering. If electric drives were excluded, it can be said that the course has not changed over a decade by considering the contents of both classical [3]-[7] and advanced [8]-[10] textbooks in the subject. As a result, the teaching way is also classical and might be boring to some extent. Electric Machines Laboratory is required to ensure that the students have good laboratory skills and practical experiences: reading diagrams, connecting circuits, using measuring instruments, as well as writing a report. It is challenging to draw attention from students, especially in the era of social media and smart devices. Students tend to lose their attention easily and frequently. Either lecture or laboratory session must be clear and concise. It is essential for an instructor to develop a learning tool to support students...
to study at their leisure time. Some supplementary materials may be removed from class and put in the internet, which are available for students to retrieve them. This learning tool has been known as e-learning [11] or virtual course [12]. For instance, the Consortium of Universities for Sustainable Power (www.cusp.umn.edu), hosted by the University of Minnesota, has provided many online course materials on power systems, power electronics, electric machines & drives, and renewable energy. Recently, blog, Line, Facebook, WhatsApp, YouTube, etc. are good example of applying social media for educational purpose.

In this paper, the instructors of the Department of Electrical Engineering, Chiang Mai University have developed video clips for Electrical Machines Laboratory and uploaded to YouTube. The video clips are provided as learning tool for students to study and review circuit connections and measuring techniques as well as prepare for the practical examination.

Section I describes electrical machines course offered by the Department of Electrical Engineering, Chiang Mai University and addresses the motivation to develop video clips as supportive learning tool. Section II describes the electrical machines laboratory – a course offered to junior students of the Department. Section III explains the process of developing video clips. Student feedback and evaluation are provided in Section IV. This work is concluded in Section V.

2. Electrical Machines Laboratory

2.1. Course Structure
Table I shows the course contents of Electrical Machines Laboratory taught at the Department of Electrical Engineering, Chiang Mai University. This course has been supervised by 3 instructors and 2 technicians. The laboratory has 15 sessions and each session is 3 hours per week. There are 9 laboratories, covering both DC machines in weeks 3-7 and AC machines in weeks 9-12. Every student is required to turn in a preliminary note at the beginning of each laboratory and turn in a report a week after completing each session. Both the note and the report must be written individually. The practical examination of each student is set in weeks 14-15. A final examination has 40 multiple-choice questions and most students would take 1-2 hours to finish up.

2.2. Laboratory Equipment and Instrument
The laboratory equipment is capable to serve up to 5 groups of students concurrently so that, the course was usually divided into 4 sections each semester. Each section has 4-5 groups. A group of 4-6 students is set for each laboratory bench. The number of enrolled students each year is 80 so that each section has up to 20 students. The laboratory equipment is illustrated in Figures 1-3. Most of the equipment shown in Figure 1 is TERCO electrical machine system (www.terco.se). The main pieces of equipment are power pack, prime mover, torque meter, and resistive load. Test machines may be added to the prime mover via a coupling shaft. The motor-control panel in Figure 2 was built by domestic supplier. Figure 3 shows common measuring tools i.e., multimeter, tachometer, voltmeter, ammeter, wattmeter, and power-factor meter.

2.3. Course Evaluation
Evaluating criteria of this course are comprehensive. The preliminary note, class participation, reports, practical examination, and final examination account for 10%, 10%, 40%, 20%, and 20%, respectively. It was found that most students have done well for preliminary note, class attention, and reports. Their scores were relatively high and not much different. But, the scores from practical and final examinations are quite different and become a grading index. Each student must take a 15-minute practical examination. A student has up to 10 minutes to set up an experiment without circuit diagram. The experiment is randomly chosen from four topics. The test topics are separately-excited DC generator, shunt DC motor, squirrel-cage induction motor, and motor control. The remaining 5 minutes is to run the experiment, as specified by the instructor, and do a
simple measurement & calculation such as efficiency. It has been considered as the most challenging part of this course. Figure 4 shows the practical examination in April 2017.

### TABLE I. LIST OF COURSE CONTENTS OF ELECTRICAL MACHINES LABORATORY

| Week | Content |
|------|---------|
| 1    | Reviews of basic concepts and principles |
| 2    | Introduction to equipment and instrument |
| 3    | Generation of electromotive force (EMF) |
| 4    | Winding factors of AC machines |
| 5    | Separately excited DC generator |
| 6    | Shunt, series, and compound DC generators |
| 7    | Shunt and series DC motors |
| 8    | Review of DC machines |
| 9    | Synchronous generator |
| 10   | Synchronous motor |
| 11   | Squirrel-cage inductor motor |
| 12   | Motor control |
| 13   | Review of AC machines |
| 14   | Training for practical examination |
| 15   | Practical examination |

Figure 1. Benches in electrical machines laboratory.

Figure 2. Motor-control panel in electrical machines laboratory.

Figure 3. Measuring instruments in electrical machines laboratory.

Figure 4. Practical examination in April 2017.
3. Developing Video Clips

The students might attempt to memorize all circuit connections of the four test topics, but it would be much effective for the students to embed their understanding into their heads. Thus, the practical examination is a driving force for developing the video clips. Besides, the student can also review other topics they are interested or missed in the class.

The instructors and technicians have planned to develop the video clips in December 2014. It took three months for scripting, shooting, and uploading. The video clips become available to the public via YouTube in March 2015. One may use the word “ee320cmu” for searching in the internet. There are 23 video clips uploaded, as shown in Table II. Most video clips are less than 5 minutes. The video clips were recorded as .mpg file by simply using a camcorder. Video clips 1-5 review the basic equipment and instrument. The remaining video clips review all laboratory topics. The motor control laboratory has 6 video clips given that circuit connections are quite complicated. The focus of all video clips is on circuit connections & tips. The procedure of running experiment was left for self-review. Nonetheless, the video clips for running experiments might be available in the future.

4. Feedback and Evaluation

In the last week of the course, a questionnaire was given to every student and the anonymous evaluation is summarized in Table III. In general, the students were pleased and found that the video clips are helpful. Numerically, only 16.7% of the students did not watch the video clips. Half of the students watched each video clip more than once. Half of the students spent 11-20 minutes watching each time. Around three-fourth of the students found that they have better understanding by watching the video clips and they could also do better in the practical examination.

| Clip | Topic                                | Duration (minute) |
|------|--------------------------------------|-------------------|
| 1    | Prime mover                          | 4:45              |
| 2    | Oscilloscope                          | 8:38              |
| 3    | Resistive load                       | 2:48              |
| 4    | Watt meter                           | 2:49              |
| 5    | Power factor meter                   | 2:43              |
| 6    | Generation of electromotive forces   | 3:51              |
| 7    | Winding factors of AC machine        | 4:01              |
| 8    | Separately-excited DC generator      | 4:26              |
| 9    | Shunt DC generator                   | 4:58              |
| 10   | Series DC generator                  | 3:41              |
| 11   | Shunt DC motor                       | 5:44              |
| 12   | Series DC motor                      | 4:02              |
| 13   | Synchronous generator                | 4:54              |
| 14   | Synchronous motor                    | 7:39              |
| 15   | Squirrel-cage induction motor        | 4:26              |
| 16   | Squirrel-cage induction motor (maximum torque) | 2:39 |
| 17   | Introduction of motor control        | 4:37              |
| 18   | Motor control – direct on line (control circuit) | 3:16 |
| 19   | Motor control – direct on line (power circuit) | 1:40 |
| 20   | Motor control – forward/reverse (control circuit) | 3:20 |
| 21   | Motor control – forward/reverse (power circuit) | 2:41 |
| 22   | Motor control – wye/delta start (control circuit) | 5:52 |
| 23   | Motor control – wye/delta start (power circuit) | 3:33 |
Figure 5 illustrates the frequency distribution of number of students taking the practical examinations, compared between 2014-2017 (before and after watching the video clips). The numbers of students in 2014-2017 are 84, 81, 82 and 106 respectively. The average scores in 2014-2017 are 14.5, 15.0, 16.0, and 16.4, respectively. The standard deviation of scores in 2014-2017 are 4.5, 5.0, 3.5 and 3.8, respectively. So, it can be statically observed that, with the increasing average score and narrower spread of scores, the student performance is better off after watching the video clips.

The number of students with full score (20) in 2014-2017 are 6.0%, 13.6%, 15.6% and 16.0%, respectively. The number of students with score less than 9 has been decreasing from 14.3% in 2014 to 5.6% in 2017. In contrary, the number of students with score more than 16 has been increasing from 40.5% in 2014 to 64.2% in 2017. Thus, it is evident that the students can perform better in the practical examinations with the help of video clips.

Figure 5. Frequency distributions of number of students taking the practical examinations.
Table IV shows the overall scores of the course, compared between 2014-2017. The average scores of these years are relatively constant but slightly higher, while the spread of scores tends to be narrower. Given that the practical examinations account for only 20% of the total scores for grading, it may not be able boost up the overall performance. By the way, it would be an interesting idea to develop a mechanism to increase the overall performance of the students.

### Table III. Frequency Distribution of Number of Students Answering the Questionnaire

| Q1  | Have you ever watched the video clip? |   |   |
|-----|--------------------------------------|---|---|
|     | Never                                | 28| 10 |
|     | All clips                            |   |   |
|     | Some clips                           | 126|

| Q2  | How many times did you watch each video clip? |   |   |
|-----|-----------------------------------------------|---|---|
|     | 1                                             | 2-3| > 3|
|     | > 3                                           | 62| 70 |

| Q3  | How long did you spend watching each time?    |   |   |
|-----|-----------------------------------------------|---|---|
|     | 0 – 10 min.                                   | 11-20 min.| > 21 min.|
|     | > 21 min.                                     | 29| 65 |

| Q4  | Did the video clips help you gain better understanding? |   |   |
|-----|--------------------------------------------------------|---|---|
|     | Good                                                    | 85| 48 |
|     | Fair                                                    |   |   |
|     | Poor                                                    |   | 3  |

| Q5  | Did the video clips help you on the practical examination? |   |   |
|-----|-----------------------------------------------------------|---|---|
|     | Good                                                      | 104| 32 |
|     | Fair                                                      |   |   |
|     | Poor                                                      |   |   |

### Table IV. Comparison of Overall Scores in 2014-2017

| Year | Max. | Avg. | Min. | Stdev. |
|------|------|------|------|--------|
| 2014 | 82.2 | 69.6 | 50.0 | 6.8    |
| 2015 | 86.7 | 69.8 | 44.5 | 8.7    |
| 2016 | 85.5 | 70.2 | 43.8 | 7.6    |
| 2017 | 84.4 | 71.8 | 45.4 | 6.6    |

5. Conclusion
The Department of Electrical Engineering, Chiang Mai University has developed video clips, using as supportive learning tool, for electrical machines laboratory. The video clips were uploaded in YouTube. The video clips enable the students to review the laboratory sessions and help them improve their laboratory skills. The students have expressed positive feedback after watching the video clips and most of them obtained higher scores in the practical examinations. Nevertheless, the overall scores of the class were slightly better off, it is thus subject to further evaluation and requires additional mechanism to improve the students’ learning performance.

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