Implementing of Activating Learning Strategy for a Course on Electric Drives

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INTRODUCTION

Effective teaching of electric drives is highly important for the electrical engineers, because almost half of the global produced electrical energy is consumed by electric motor drives [1]. Electric drives are a key technology for reducing energy consumption of industrial processes, for wind power generation and for electric transportation. The pedagogical premise is to improve the educational methods of an Electrical Drives course by activating students to work on their own. The paper describes the educational strategy and course objectives. Student feedback was collected at the end of the course and the results of the evaluation are summarized.

1 EDUCATIONAL STRATEGY

Today's information community expects graduate students to be able to apply the specific knowledge to solve complex problems in an efficient way and, therefore, the students should activate toward self-directed lifelong learning process [2]. Instead of traditional education methods, the active learning methods should be used to provide required knowledge and skills to students' future career development [3]. Active learning engages students in doing and thinking about the things they are doing [4]. Students participate in the process when they are doing something besides passively listening [4].

In the past years, two separate courses about electric drives were organized: the first course has been conventional lecture-based course and the other one the laboratory

course. There was pressure to renew the courses because of fast development in the field of power electronics. These two courses are integrated, because the students need to be able to combine the theoretical knowledge as well as practical knowledge.

Students are motivated when they value what they are learning. Therefore the target of the lectures is to motivate the students to learn by themselves by using the real-world examples. The course content is divided into large topics, which include lectures, calculation, simulation as well as laboratory exercises in each topic. Therefore the target is to understand these large topics instead of individual pieces of information. According to Bloom's taxonomy, the target is not only to remember the issues, but also understand and be able to apply the knowledge into new situations.

The course provides not only required basic knowledge about electrical drives but also increase students' problem-solving and team-work capabilities [5-8]. The working methods, which are required during the future career are used in the activating learning method: team-work skills, team management skills, debugging skills and technical report writing skills [5-8].

Target is to use different teaching methods in various ways and therefore each student can choose the learning method which is the most suitable for them. The only requirement for passing the course is accepted exam, but additional points to the exam are given from all the exercises during the course. The target is to activate students to work by using the same kind of working methods as in their future career [5-8].

2 COURSE CONTENT

Electric Drives is a first-year course for master degree students who are studying Power Electronics as a major in Tampere University of Technology, Finland. In addition, some students, who are studying Mechanical Engineering or Automation Engineering as their major, take also part to the course. The course is conducted over 7 weeks.

The target of the course is to give the basic knowledge on operating principle and control method of DC drive, asynchronous motor drive and synchronous motor drive. In addition, the protection of the motor drive and the effect of the motor drive to the grid currents and power factor are shortly analyzed. The students will be able to choose the suitable motor and converter size and type depending on the application. In the end of the course, the energy storages, i.e. batteries and supercapacitors are shortly presented and the applications in electric vehicles and electric or hybrid working machines are presented according to the research group worked in the Department. In addition to the preliminary learning objectives, the students will improve their other capabilities such as team-work, team-management, time scheduling and technical writing.

The detailed course content is presented in Table I. Introduction to each topic is presented in the lectures. Thee-hour interactive lectures are organized once a week. The course content is organized by using step-by-step method starting from basics of motor drive, such as definition of torque and power. The previous knowledge is used as a base to study the new things. Students reflect their own learning, because summary of the last lecture is done always in the beginning of the next lecture by asking review questions from students.

Students are encouraged to be active during the lectures. Teacher asks questions trying to increase students own thinking. The target of the questions asked during the lectures and exercises are tried to answer always to question "why", not just only

"what" or "how". The questions are open-ended and there might be multiple correct answers. Concept maps are used to illustrate the connections that exist between terms or concepts covered in course material. The examples from the industry are always used when it is possible.

Table 1. Course Syllabus

Week	Topics	Exercise
1	Introduction to course: goals and working principles Motivation: Need of electric drives Basics of mechanics, torque and power, typical torque curves, gears	Calculation exercise: torque, power and gears
2	Choosing of suitable motor drive Protection of motor drive	Calculation exercise: choosing of suitable motor drive (motor losses, maximum torque and power)
3	Operation principle of DC motor DC motor drives DC motor control	Simulation exercise: Separately excited DC motor supplied by a thyristor-rectifier
4	Operation principle of asynchronous motor Induction motor drives Doubly-fed induction generator (DFIG) Starting methods of induction motor Scalar (V/Hz) control of an induction motor	Laboratory exercise: Separately excited DC motor supplied by a thyristor-rectifier Simulation exercise: induction motor (directly grid connected and with open-loop scalar control)
5	Basics about field oriented control (FOC) and direct torque control (DTC) Visit: electric vehicle	Laboratory exercise: induction motor drive (directly grid connected, open-loop scalar control, DTC) Calculation exercise: choosing of suitable motor drive (maximum losses and torque curves)
6	Operating principle of synchronous machine (PMSM, reluctance motor and separately magnetized synchronous machine) Synchronous motor drives Effect of motor drive to grid: harmonics and power factor Energy reserves and regenerating braking	Simulation exercise: PMSM servo drive
7	Visiting lecture: FEM modeling and iron losses in a motor Recap & getting ready for the final exam	Laboratory exercise: PMSM servo drive Essay: application of motor drive

YouTube-videos are used to illustrate complex, three-dimensional operation method of the motors. Few questions about the motor operation are asked before the video hence the students can pay attention to important facts and the discussion about these topics is done after the video [9].

The lecture material is totally renewed and done in English hence students will learn the important terminology in English and they are able to find more information about the topic. All the lecture material is available in the course website allowing the possibility to study independently.

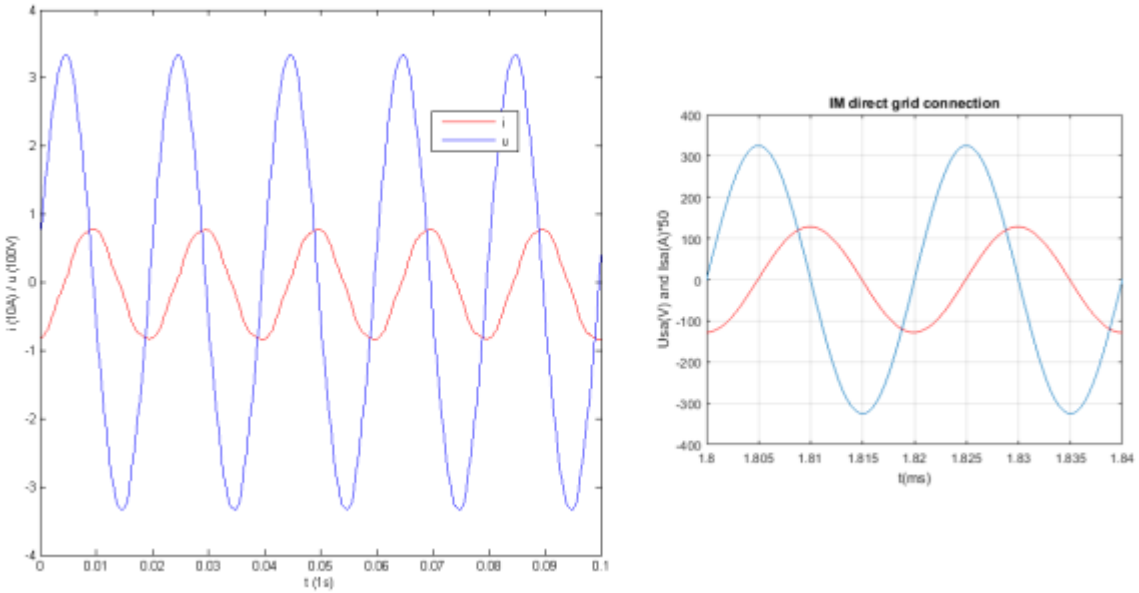
After the lecture, the students are able to continue their learning process with calculation, simulation and laboratory exercises. The exercises are done in the groups of three students. Formerly, majority of the students did not do the exercises, because there was not any incentive. Therefore the students got additional points to the final exam grade if they solve the exercises in the new course. The advising hour is organized every week in the PC classroom, were students are able to do their exercises independently but the teacher is available if some problems occur. The students thought that these sessions are very useful.

The students return the results of the calculation exercises to the instructor by e-mail or attend the exercises, where the students present their answers at the blackboard. The method is motivating, because there are multiple ways to solve the same problems. The real-world examples are used in the calculation exercises and independent exercises forms the totality supporting the knowledge got from the lectures and this knowledge is also used during the simulation and laboratory exercises.

The simulation exercises are added to the course, because the ability to use Matlab Simulink in the following courses is very important. In addition, the work in the laboratory is more effective when the students are analyzed the motor phenomena beforehand by using the simulation model. The creating of the motor models will be studied in the following courses. Hence, in this course, the already-done simulation models provided by Matlab SimPowerSystem toolbox are used.

Before coming to the laboratory, the answers to the preliminary questions were returned to the teacher. The basic operation principles of the laboratory system were asked in the preliminary questions. The questions were e.g. how the rotating speed of the DC machine can be changed, how the armature voltage amplitude can be controlled and what means 4-quadrant operation of the machine. The actual industrial devices, which students might encounter in industry, are used in the laboratory. The measurements are done in the laboratory by using DAQ-measurement card by National Instruments. Therefore the measured results as well as the simulated results can be easily plotted to the same figure by using Matlab and the similarities as well as differences between the simulated and measured results are easy to compare.

The operation principles of the most used motor drives in different situations were analyzed in the laboratory. For example, the ABB ACS 800 power converter is used in front of the 2.2 kW induction machine. The load is 6 kW DC machine. At first, the direct grid connection of the induction machine with or without the load and in motor as well as in generation mode is tested as shown in Fig. 1. Later on, the operation of direct grid connected induction machine and the induction machine with the power converter are compared.



a) b)

Fig. 1. a) measured and b) simulated grid current (red) and grid voltage (blue) without the load when the induction machine is directly grid connected

The frequency reference value in the scalar (V/Hz) control and the effect of IR-compensation with low rotating speeds are analyzed as shown in Fig. 2. In addition, the effect of motor control method to the grid currents and grid current harmonics is analysed. Finally, the accuracy of the scalar and DTC control methods were compared by using step tests. The diode rectifier is used with the induction machine but active grid converter is connected in front of the servo drive. Therefore, the effect of the active grid converter compared to conventional diode rectifier is shown. The effect of the PI-control parameters to the position control accuracy is also analyzed with the servo drive.

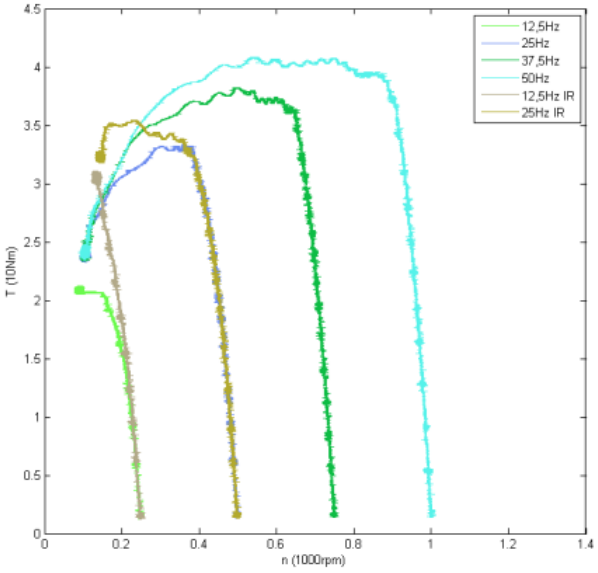


Fig. 2. Measured torque as a function of speed when the induction machine is controlled with V/Hz-control by varying the frequency reference or by adding IR-compensation

The simulation and laboratory work are reported by writing a professional report. The report includes a cover page, an abstract, a summary of the theory about the related topic, simulation results, measured results and the analysis about the results.

The last exercise of the course is to write a short essay about some motor drive application depending on the students' own interests. The students find information, how large and what type motor drive is used, what kind of control and safety issues need to be considered in the chosen application. The students analyzed e.g. electric vehicles, NC machine tool, cable crane and elevator.

The students were highly interested in electrical vehicles and therefore visiting lecture was organized, were the ongoing electric vehicle research project was presented. Moreover, the other visiting lecture was organized by a professor specialized into FEM-modeling and power losses of motors. The target of the visiting lectures is to motivate the students to study the electric drives in more detail in the future.

3 STUDENT ASSESMENT

Student feedback was collected at the end of the course. The questionnaire included the questions about the time consumption, overall grade of the course, how well the course supported the learning goals and open space to positive or negative feedback of the course. The number of participated students was larger during the year 2015, 34 students compared to 19 students during the year 2016. However, the same amount of students participated in the laboratory course last year as in Electric Drives course during this year.

Time consumption of the courses is presented in Fig. 1. Majority of the student thought that the workload of the new course is reasonable as shown in Fig. 1 in spite of the fact, that 5 cr theoretical course and 3 cr laboratory course are combined into one 5 cr course including additional simulation exercises, essay writing and visiting lectures. Some students claimed that there were too much work with the simulation exercises and laboratory reports or there were not enough time for these. 5 cr means approximately 140 hours work, including 60 hours contact teaching and 80 hours independent work. The students are not written before many technical reports and therefore it was difficult for some of the student groups. Teacher corrected the report and returned it once to the group to correct the mistakes, if required.

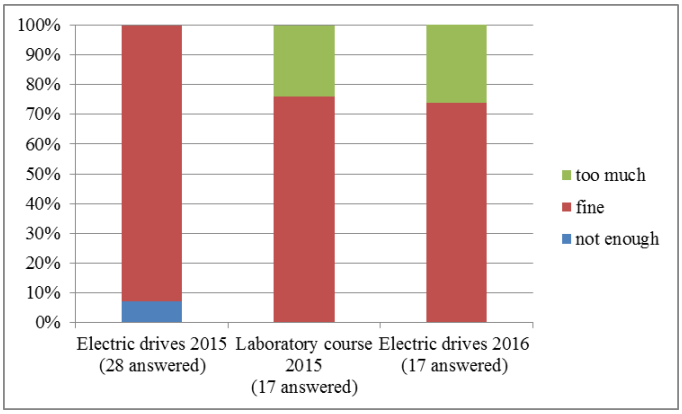
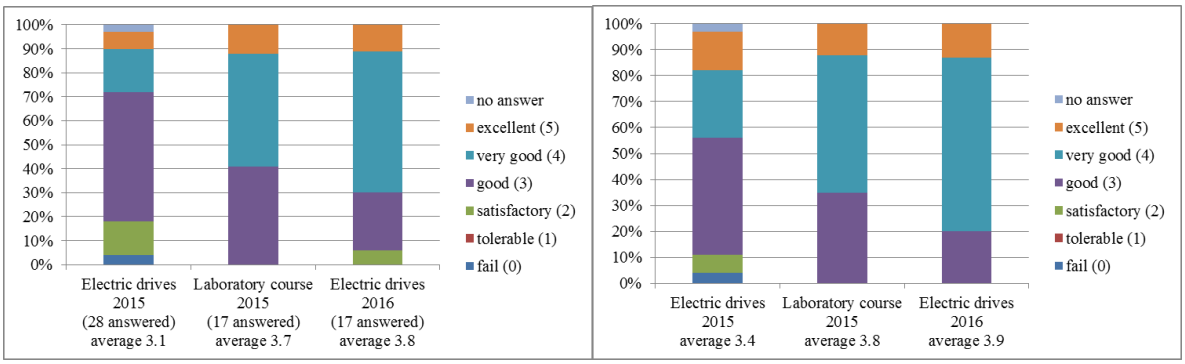


Fig. 1. Time consumption of the courses

The students thought, that there were open and inspiring atmosphere during the whole course. The students gave positive feedback of the overall course structure. Majority of the positive feedback was concentrated into the laboratory and simulation exercises. The average course grade increased in spite of the increased workload

hence in can be concluded that the practical work motivates the students much more compared to conventional lecture-based teaching as shown in Fig. 2.



a) b)

Fig. 2. a) Overall grade to the course and its implementation and b) how well the course supported the learning goals

The course grades are shown in Fig. 3. The old laboratory course was graded only as pass or fail. The average grade of the final exam increased from 2.9 to 3.3 and all students passed the exam during the year 2016. The course grade was possible to increase by one grade if all the exercises and laboratory as well as simulation reports were done properly. Only two students did all the exercises achieving all the bonus points, but all students did at least part of the exercises.

The target of the exam was to test, that the students are not only able to remember some issues but also apply them and define the reasons for some operation methods or applications of the electric motor drives. The student needs to be e.g. explain, what problems are caused of direct grid connection of induction machine and why and how these problems can be solved. The student needs to know, why power losses occur in machines, how the losses can be minimized and how the power converter affects to the power losses. The students thought that the questions in the exam were well related to the important topics analysed during the lectures and laboratory exercises.

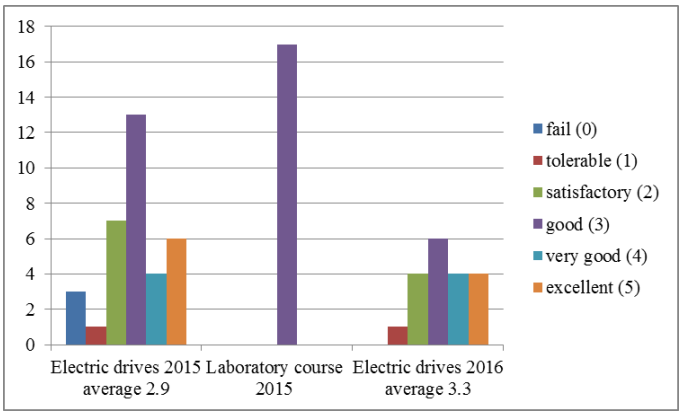


Fig. 3. Course grades

4 SUMMARY AND ACKNOWLEDGMENTS

The target was to improve the educational methods of an Electrical Drives course by using an activating learning method. According to the presented results, the used methods leads to better learning results, higher enthusiasm into the topic and better capabilities to continue studying in the future courses as well as capabilities needed in the future engineering career.

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