

# Adaptation of the Electric Machines Learning Process to the European Higher Education Area\*

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*In this paper the basic lines of a complete teaching methodology that has been developed to adapt the electric machines learning process to the European Higher Education Area (EHEA) are presented. New teaching materials that are specific to Electric Machines have been created (textbooks, self-learning e-books, guidelines for achieving teamwork research, etc.). Working in groups has been promoted, as well as problem solving and self-learning exercises, all of which are evaluated in a way that encourages students' participation. Finally, the students' learning process in the lab has been improved by the development both of a new methodology to follow in the lab and new workbenches with industrial machines that are easier to use and also enable the lab experiments to be automated. Finally, the first results obtained as a result of applying the proposed methodology are presented.*

**Keywords:** electric machines; learning systems

## 1. INTRODUCTION

RECENT CHANGES IN STUDY PLANS for the Industrial Engineering degree have brought about a large reduction in the teaching hours allocated to the basic contents of the topic of Electric Machines. In order to avoid reducing the contents along with the reduction in class hours, a new teaching methodology is needed to stimulate the students' self-learning.

In the last few years, the structure of the academic programs that offer an Industrial Engineering degree have been subject to continuous change. In the specific case of the Universidad Politécnica de Madrid (UPM), two changes should be pointed out: in the year 2000 a new study plan was introduced and the European Higher Education Area (EHEA, 1999 Bologna Declaration) requirements to the Spanish teaching system have been implemented (in 2005).

With the aim of unifying the different degrees (in contents, classroom hours, total working hours, etc.) in order to facilitate student and teacher mobility between EU countries, The European Union has created what is called the European Higher Education Area (EHEA). This common educational institution is based on a credit system called ECTS (European Credit Transfer System) whose purpose is to improve the follow up by the professors of students' work and the learning process [1]. In Spain, in particular, this will imply, among other things, that in the near

future there will be a single engineering graduate program degree. This will require adaptations of the first courses [2]. Currently, in addition to the five year engineering degree, there is also a three year program that offers a 'Technical Engineering Degree', and the student who wants to continue with his or her studies must follow a Master's degree and, later on, a Ph.D. program.

On the other hand, in the year 2000 the Escuela Técnica Superior de Ingenieros Industriales (ETSII) at the Universidad Politécnica de Madrid (UPM) changed the curriculum that had been established in 1976 (Plan 76), which had been based on a six year program. In the old program the different subjects were taken annually throughout the whole academic year. The new curriculum consisted of five years with biannual subjects (plan 2000). This new plan has meant a significant change in the contents of the topic 'Electric Machines'. This was the motivation for creating the Educational Innovation Group of Electric Machines (GIEME). This group has implemented a series of measures to help the students by improving the learning process for this subject.

In 2005, the UPM began to encourage and give financial support to projects aimed at unifying it with the EHEA teaching system. It was the intention of these measures to encourage the necessary changes in the teaching methodology in order to move slowly away from the traditional educational system, which was usually based on lectures, to a new teaching methodology that focused on student learning. The implementation of this new teaching methodology facilitates the control of the programs and allows the students more time to

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practice and learn. All these innovations will facilitate the creation of a four year engineering program in the near future [3]. In this field, GIEME has developed two innovative educational projects, the objectives and results of which are explained in this paper.

## 2. APPROACH

As mentioned above, with the Industrial Engineering reform at UPM in the year 2000, an important change took place within the topic of Electric Machines. First, it must be mentioned that the available class time spent on teaching the basic contents of electric machines has been considerably reduced. Tables 1 and 2 show the distribution of hours available in the classroom for teaching the basic contents of the electric machines course, both for the 6 and 5 year plans for the Electric Engineering specialization. In fact, in these tables each classroom hour is equivalent to fifty minutes of effective classtime. The basic contents of the Electric Machines course includes transformers, AC rotating machines (asynchronous and synchronous), DC machines and electric drives.

From the data in Tables 1 and 2, it can be deduced that the changes in the study plan have meant a reduction of 47.4% in the classroom hours spent on teaching the basic contents of Electric Machines, as well as a reduction of 65.6% in the hours spent on laboratory teaching.

Besides this serious reduction, it has to be pointed out that what is taught in the 5th semester in Plan 2000 is also commonly taught to all the Industrial Engineering specialty students and not just to the Electric Engineering students as stipulated in Plan 76. This change not only affects the teaching methodology, because now the course is taught to a larger number of students, but it also means that it must be taught in a more general

Table 1. Hours spent on teaching the basic contents of electric machines in Plan 76 (4 semesters out of 12)

Semester	Classroom hours	Lecture hours	Practice hours	Lab. hours
9th	75	50	25	16
10th	90	60	30	20
11th	75	50	25	16
12th	45	30	15	12
<b>Total</b>	<b>285</b>	<b>190</b>	<b>95</b>	<b>64</b>

Table 2. Hours spent on teaching the basic contents of electric machines in Plan 2000 (3 semesters out of 10)

Semester	Classroom hours	Lecture hours	Practice hours	Lab. hours
5th	45	30	15	6
6th	60	40	20	10
7th	45	30	15	6
<b>Total</b>	<b>150</b>	<b>100</b>	<b>50</b>	<b>22</b>

way, a way that would be different if it were only taught to the Electric Engineering students.

On the other hand it should be stated that in Plan 2000 two new subjects were introduced that did not exist in Plan 76. The new subjects were 'Electric Generation with Renewable Energies' and 'Electric Drives Control'; these subjects attempt to bring traditional contents of the electric machines course up to date and to get closer to the reality of the present electrical sector. It should also be taken into account that the creation of these two new subjects has partially contributed to the already-mentioned reduction in the lectures and practical classroom hours left to cover the basic contents of Electric Machines.

Also, because of the net reduction of teaching hours introduced with the new plan of studies, it has been necessary to develop some specific measures to facilitate a better understanding of the basic aspects of electric machines. To deal with this new situation in the best possible way, the following course of action has been established:

- a new arrangement (by semesters) of the basic contents of electric machines;
- the establishment of educational objectives;
- the implementation of new teaching methodologies;
- the development of new laboratory teaching techniques;
- the creation of better teaching materials.

## 3. NEW ARRANGEMENT OF THE BASIC CONTENTS OF ELECTRIC MACHINES

In Plan 2000 the basic contents of the Electric Machines course are included in three different courses: Electric Machines I (5th semester), Electric Machines II (6th semester) and Control of Electric Machines (7th semester).

The first class is a requirement for all Industrial Engineering students (~400 students) and because of this it should give a general overview of the subject matter. It should include the basic study of transformers and AC asynchronous machines. In this way, all the Industrial Engineering students will acquire clear notions of the two most common electric machines used in industry.

The Electric Machines II course (6th semester) is offered to those students who have chosen Electric Engineering as their major field of studies (~80 students). The first purpose of this class is to reinforce the knowledge of transformers and AC asynchronous machines acquired in the course 'Electric Machines I'. The second purpose is to study synchronous machines as most electric generators are of this kind, as well as DC machines because the knowledge of their use and their regulation are very important in later studies of different control systems of electric machines.

The course 'Control of Electric Machines' (7th semester) is also only offered to Electric Engineer-

ing students. Its contents are based on the study of electric drives and basic control systems applied to DC and AC machines.

With the exception of this last course where the contents of the subject matter and the teaching hours are similar to that offered in the 12th semester in Plan 76, the other two courses have suffered a severe reduction in the time available for them. In order that this reduction does not affect the basic contents of their classes, it has been necessary to establish a new methodology to make the most of the teaching hours and to stimulate the students' learning processes.

The implementation of this new methodology has been backed up by big changes in the laboratory working mode, such as the equipment (test working benches, measurement and data acquisition devices, power converters, etc.), and also changes in the experiments to be performed. In addition, new supporting teaching tools have been incorporated (new texts, self learning units, laboratory guidelines, etc.) that were not available in the previous teaching plan.

#### 4. EDUCATIONAL OBJECTIVES FOR THE NEW TEACHING METHODOLOGIES

The main objective of the teaching methodology proposed here is to maintain, and hopefully improve, the teaching level, both in contents and students' learning, in spite of the reduction in the available teaching hours.

In addition to the cognitive objectives of each subject, which have been revised for modernization, the new proposed methodology covers new objectives to strengthen the students' competencies in areas such as:

- practicing teamwork techniques;
- practicing public exposition of their work;
- bibliographic searches;
- reinforcement of oral and written knowledge of the English language;
- dealing with the computerized media (hardware and software).

Since the degree of achievement of the main objective of this methodology is not easily measurable, other objectives that can be quantified after its implementation have been adopted as the criteria for comparing the results obtained with this methodology with those achieved with the traditional method used previously. In this way, the indicators of success at reaching the main objective proposed here can be as follows: An improvement in the number of students who pass the subject, and a rise in the students' mean final grade in the subjects taught. Below, we describe how the results obtained according to these last criteria can be observed when this methodology is applied to a particular subject.

#### 5. IMPLEMENTATION OF THE NEW TEACHING METHODOLOGIES

From the new EHEA's guidelines that the Engineering graduate students will be following one can foresee that there will be an even a larger reduction in classroom hours in many subjects than currently exist in Plan 2000.

This new situation involves continual changes in study plans and assessments in most of the technical schools in addition to the re-evaluation of several university degrees to adapt to the EHEA. This has forced those in the university teaching profession to get involved in an in-depth analysis of the time needed to produce good professionals. They concluded that it is first necessary to evaluate the time spent on each activity of every class. Secondly, each professor must carefully measure the valuable time available in and out of his or her class, in the laboratory, tutorials, etc.

With these goals in mind, the GIEME group has encouraged the following measures:

- To guide the students in their learning process when dealing with the contents of specific subject matter through the development both of self-learning tools based on electronic formats (e-learning) and by offering a specific bibliography to be consulted. The use of e-learning tools is highly desirable for the study of electrical machinery, achieving success even at pre-university education level [4]
- To improve the students' practical abilities by reforming the teaching techniques used in the laboratory
- To put the students in closer contact with real industrial installations that use machines studied in the classes. This can be done in working groups to achieve a better understanding of the actual equipment and through field trips to the plants where they are installed.
- To encourage working in groups (cooperative work) and increasing the active participation of students in class by carrying out group tasks and giving presentations to the rest of the class, and also to solve special problems in groups while in class, etc. [5, 6]
- To make a more detailed follow up of the students' learning process by promoting their attendance at tutorial classes
- To make an objective evaluation of the knowledge and other skills acquired by the average student in every class and compare these results with the starting expectations
- To measure in hours the effort that the average student has to make in order to acquire sufficient knowledge to pass the classes.

Below, the actual activities that need to be implemented when establishing the new teaching methodology for the 'Electric Machines II' course are presented as an example. First the two objectives that are absolutely necessary and that have to be implemented before adapting the new teaching

methodology are presented. These are: the modification of the teaching methodology in the lab and the development of new teaching material.

## 6. REORGANIZATION OF TEACHING IN THE LABORATORY

As mentioned above, the implementation of Plan 2000 has brought about a 65.4% reduction in laboratory teaching hours, compared with that for Plan 76. In order to prevent this drastic reduction in time from leading to a similar reduction in content it is necessary to do the following.

- Redesign the lab sessions by merging those with similar contents and instrumentation. With this step, it has been possible to reduce the laboratory sessions from 16 hours (Plan 76) to 11 hours (Plan 2000).
- To reduce the length of each laboratory session without diminishing the subject matter. Specifically the 4 hour sessions in Plan 76 have turned into 2 hour sessions in Plan 2000.

In order to achieve the above-mentioned reduction, the following actions have been taken:

- Making up new laboratory session guidelines
- Designing and manufacturing new laboratory workbenches
- Automation of the laboratory sessions.

### 6.1 New laboratory sessions guidelines

A guideline for each practice lab has been created: a clear explanation of its theoretical basis can be found together with a specific description of the electric wiring to be done.

These guidelines can be downloaded from the intranet in advance, using the AULAWEB e-learning system [7], to allow the students to study them before beginning the practice lab. In order to stimulate the students' learning during the practice session, a 10 minute quiz is given at the beginning of each session with questions dealing with the contents of the guideline.

These quizzes have taken the place of the two lab final exams that were given in Plan 76 at the end of the 10th and 12th semesters and that used to take up 8 hours of the officially assigned lab hours.

In addition, the implementation of the new lab guidelines eliminates the time that the professor used to spend explaining the use of the lab in Plan 76. It is important to point out that for each lab session 1.5 hours were spent giving information and therefore the new guidelines save 21 hours. If we add these hours to the 8 hours saved by eliminating the final lab exams, we have reduced the 64 hours in the lab of Plan 76 to 35 hours in the new plan.

If, from the 22 lab hours of Plan 2000 we subtract the time spent on the 10 minute quizzes given at the beginning of each lab session, 20 hours of hands-on practical lab hours are obtained.

Keeping in mind this achievement, we have a reduction of 42.8% in the effective lab time (versus the 64.5% reduction of real hours).

In order to maintain the contents of the lab classes in spite of the reduction of effective lab hours, it is necessary to speed up the realization of the machines' tests. In order to do that, it is essential to have very clear guidelines and workbenches designed to simplify the electric assembly, and that the measurements and calculus is automated [8].

The actions carried out to achieve these last two goals are described below.

### 6.2 Development of new workbenches for lab classes

Each workbench is composed of three 4 kW industrial machines coupled on one axis, where there is also a torque-meter and a speed one (encoder). These three machines are: a squirrel cage asynchronous machine, a synchronous machine and a DC machine. In addition, each workbench has a panel where, besides the security terminals for the three machines, all the measurement devices are integrated [9]. Having this arrangement with them in the same panel clarifies the connections and, therefore, as well as reducing the time spent on it, it substantially increases the security in the lab and is a reasonable alternative to Virtual Laboratories (VL) [10, 11]. The general arrangement of the workbench is shown in Fig. 1.

In order to bring the student closer to the industrial real world, industrial machines have been used in preference to designs made specifically for lab work. The three machines have been included in one bench so that it can be used for all kinds of practicals, and the students do not have to learn the functions of several benches, with the consequent waste of time involved.

### 6.3 Automation of practicals

The workbench offers the possibility of doing automatically, after the measurements have been taken, the necessary calculations to be solved after each test. In order to achieve this, the necessary measurements are taken (i.e. voltage, current, torque and speed) by means of the transducers that adapt the measured signals to the proper voltage levels to fit to the input channels of a data acquisition (A/D) inserted on a PC.

This automatic system of measurements and calculation for the laboratory sessions is used simultaneously with the manual system used with measurement devices shown in the connection panel of Fig. 1. The student must do the practical manually and should compare his or her own results with those obtained with the automatic system. The acquisition data and the calculation made by the computer in real time during the laboratory session (see Fig. 2) help the student to verify the measurements and results that he or she is obtaining [9]. This ability to allow students to correct their own work stimulates their learning.

In addition to this, the automation of the lab

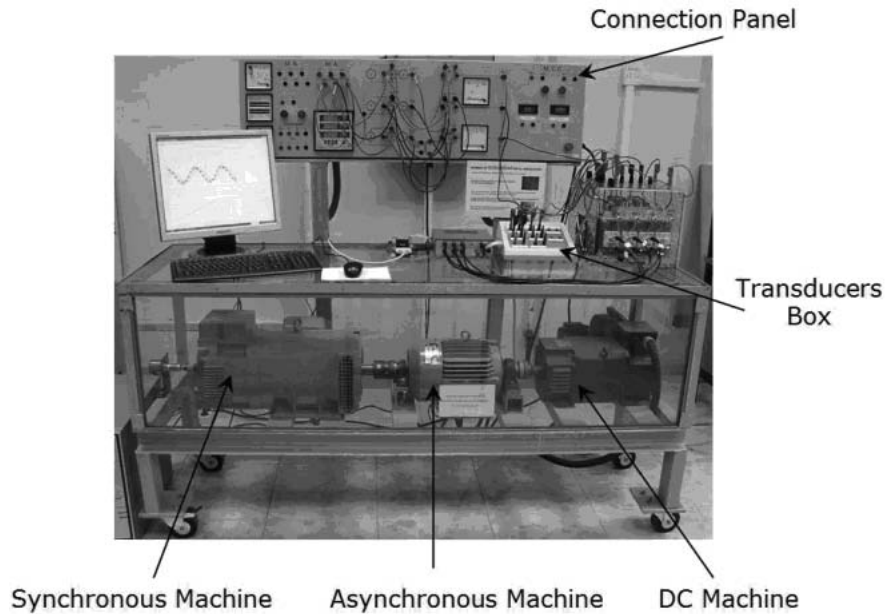


Fig. 1. General arrangement of laboratory workbench.

practicals, together with the security considerations mentioned above, make it possible for the student to enter the lab after hours and use the workbench on his or her own to reinforce some parts of the practice already performed with the minimum assistance of laboratory personnel [10] and without the presence of a teacher.

The actions mentioned have been implemented one at a time, as the new equipment became available; most of them were not applied immediately after the Plan 2000 started. The general procedure for introducing the new courses of action into the lab sessions is that first they are introduced into the subject in the old plan in order

to test the students' responses. In this way it has been possible to make improvements in class until the new courses are definitely ready to be implemented. This was the case for the lab guidelines and the previous quizzes. The new workbenches and new measurement automation systems were being in development for two years before they were ready to use.

The developed lab materials, guidelines and quizzes received very different reactions from the students. While the lab session guideline had a very positive reception from the students, the previous quizzes were adopted with reticence in the first sessions. Nevertheless, as a result of the new mate-

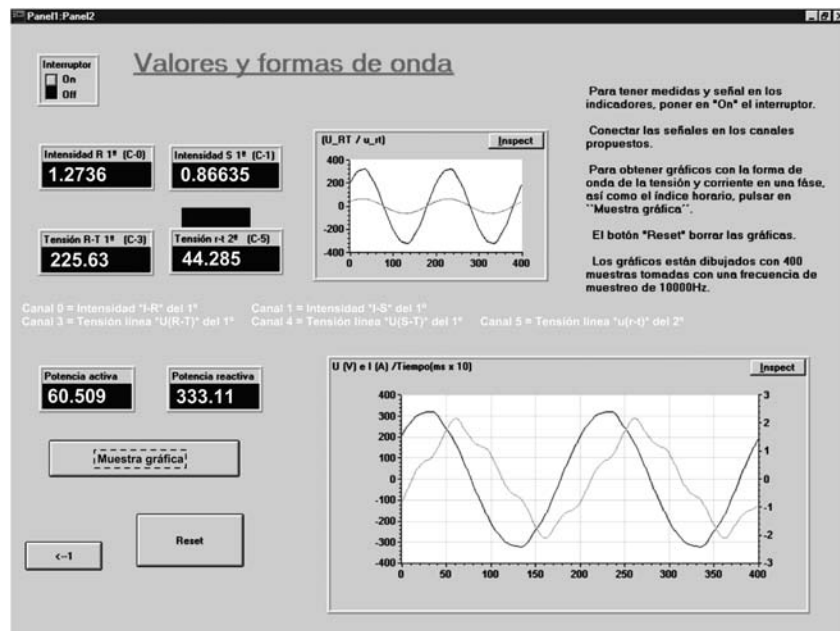


Fig. 2. Practice screen panel in automatic mode.

rial and the new workbenches, the security and the timelines of the laboratory tests, the students' performances have improved, which has given the students the feeling that they are making better use of their time. The educators have realized that this fact has stimulated the students and has awakened their interest for the lab sessions.

## 7. CREATION OF NEW TEACHING MATERIAL

It has already been mentioned that the implementation of Plan 2000 has brought about a 47.4% reduction in the hours assigned to classroom teaching. In order that this time reduction does not affect the knowledge of the basic contents of electrical machines acquired by the students, new teaching materials that combine traditional tools with innovative ones have been developed.

An important part of the basic contents is taught in class in a traditional way with the support of two textbooks that have been specifically written for this purpose:

- *Transformers and Asynchronous Electric Machines*, Madrid 2004 [12];
- *Synchronous Machines and Direct Current Machines*, Madrid 2007 [13].

Before the publication of these books, there was not a preferred textbook to follow in class. A general bibliography was suggested to the students, which covered a wide area compared with that taught in class. Although this facilitated the development of students' competences such as resuming and synthesizing, it was time consuming. Now, with the new teaching methodology, these competences are now developed through activities such as teamwork research.

The great advantage of these two textbooks is that both are specifically adjusted to the contents of the subject matter of 'Electric Machines I' and 'Electric Machines II'. This way, both books present the material of the basic theoretical concepts of

electric machines in a similar way to the material taught in class, so they can be used as a quick support to prepare the class in advance or simply as a reference to correct and complete the notes taken in class. In addition, they include a collection of solved problems that contributes extensively to guiding the learning process of the students.

With the basic concepts already learned, the students can be encouraged to learn from their own specific material. As a first experience it has been decided to encourage self-learning to master specific material dealing with the class 'Electric Machines II'. The chosen material covers cognitive objectives whose level of competence is basically 'knowledge' according to [14]. Two teaching tools have been developed (Fig. 3):

1. A self-learning multimedia tool entitled *Complements of Electric Machines* has been published in electronic book format [15]. In this e-book more advanced and detailed material about transformers and asynchronous machines is introduced. This new material allows the students to increase their knowledge of materials already covered in the 'Electric Machines I' class [16].

In the next section, this e-book is described in detail. It's important to keep in mind that adopting this book in this class will allow more teaching time that can be spent on other learning activities such as problem solving and team work presentations.

2. *A Guideline for developing group research*. Technical information of different high power electric machines used in real installations (industrial plants, power stations, train traction systems, etc.), has been collected and organized. Each semester, one of these machines is chosen and its individual systems and structure are analyzed in detail by each group of students. By doing this, the whole class will study the same machine, but each group, made up of three students, will describe in detail one part of the machine or a system linked to its function

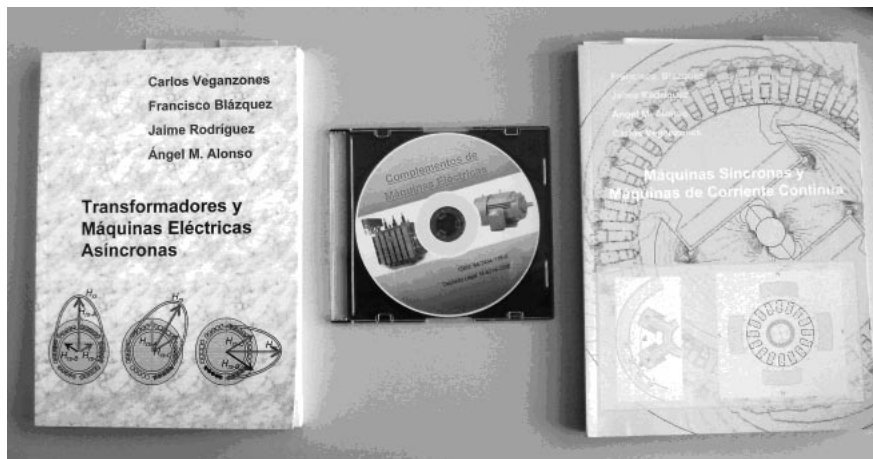


Fig. 3. Textbook and e-book covers.

or protection. Thus, they will increase their knowledge of these machines used in real installations. For example, the teamwork prepared for the year 2008 was focused on deepening the students' knowledge of synchronous machines. A wide spread of information about a big synchronous generator was available to the students, and the topics that were proposed to the teams based on this machine were: 1) Excitation system; 2) Voltage regulation; 3) Turbine and speed regulation; 4) Types of windings; 5) Cooling system; 6) Protections; 7) Tests; 8) Instrumentation; and 9) Maintenance. The teamwork forced students to do a bibliographic search and to deal with the actual equipment and industrial installations. On the other hand, this experience was challenging for the students as they had to prepare and present a public presentation of their work [17]; meanwhile the spirit of working in teams was promoted. It must be mentioned that the high quality of both reports presented by the students as well as the public presentations was surprising.

### 7.1 The electronic book 'Complements of Electric Machines'

Some specific contents of electric machines, such as the interaction of rotating fields and the torque created, become a more interesting subject to teach with the help of an electronic book, which provides more tools to master this complex subject and, also, offers more learning support [18]. The multimedia computer applications offer some well known advantages such as student interactivity, and also, allow an explanation of some of the phenomena of electric machines through animation as well as the simulation of some electric

processes that can not be taught without this methodology [19].

In order to implement this self-learning tool the dynamic HTML computer language has been used to offer a web environment of easy access, which facilitates the students' interaction. In addition, the JavaScript computer language has been adopted for the design of the graphic applications and the self evaluation exercises.

The e-book consists of two modules: one dealing with transformers and another with asynchronous machines, both sections are interactive, trying to keep the students attention according to the computer possibilities [20]. It must be remembered that the basic theory concerning these two electric machines is well known by the students because it has already been studied in the subject taught in the previous semester. Thus, the purpose of this e-book is to reinforce their knowledge.

The different chapters contained in the transformers section are as follows: 1) Three phase transformers under unbalanced load; 2) Magnetization current in a transformer; 3) Types of transformers and most common connections; 4) Standards; 5) Voltage regulation; Tap transformers; 6) Transformers for measurement and protection.

The following chapters cover the specific contents concerning the Asynchronous Machines section: 1) Winding factors: distribution and path shortening; 2) Single-phase induction motor; 3) Asynchronous generator: Isolated and grid connected; 4) Starting of asynchronous motors; 5) Speed regulation; 6) Motor selection. Specifications.

Both sections include interactive exercises for self evaluation (questions and problems), the purpose of which is to allow the students to measure the knowledge that they are acquiring,

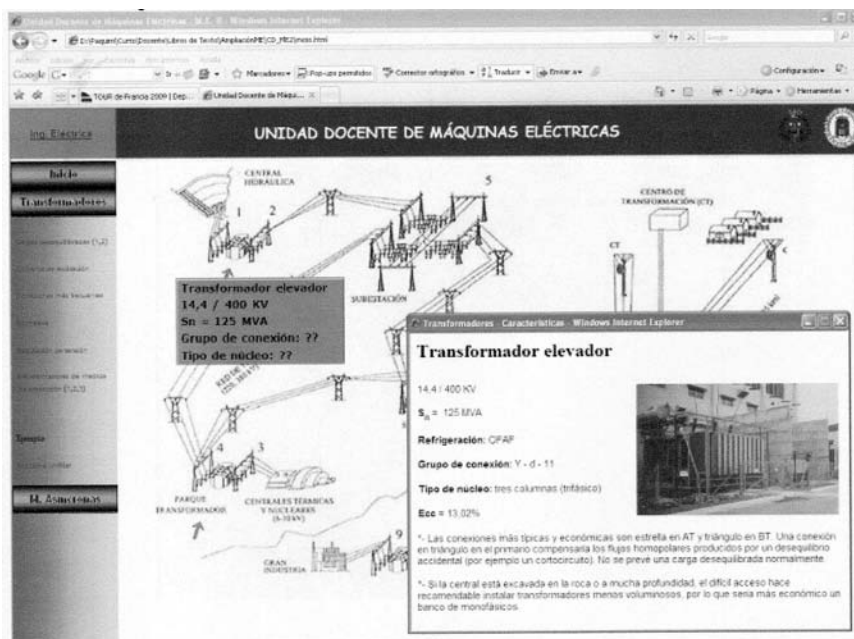


Fig. 4. Screen of the transformers module of the e-book.

thus motivating their participation while reading this document.

Figure 4 shows a screen of this electronic book.

## 8. APPLICATION EXAMPLE: INNOVATION IN THE TEACHING METHOD IN THE ELECTRIC MACHINES II CLASS

This work was developed within the framework of the educational innovation project ‘Innovation in the teaching of electric machines for its adaptation to the European credit system ECTS’ financed by the UPM. In particular, the purpose of this work has been to adapt the teaching methods of the class Electric Machines II to the new European university teaching system. In general, the following objectives were pursued:

- To provide the student with teaching tools to improve his /her academic results and to reduce the hours needed in the learning process. This goal was accomplished with the development of a book, *Synchronous Machines and Direct Current Machines*, as the basic textbook for the subject, with the development of the e-book *Complements of Electric Machines*, as a self learning tool, and with the development of some guides containing the information needed for doing research work in groups.
- To establish a continuous evaluation system of the students’ work and learning as well as a quantification of the hours spent in these endeavors. This measure is essential in order to evaluate the educational validity and consistence of the new educational plan to be established, since the way finally to prove the viability of that plan will be through the average student’s ability to follow the course.

The most relevant points concerning the implantation of the ECTS credit system for the Electric Machines II course will be explained.

### 8.1 The new teaching methodology used in the Electric Machines II class

The new teaching methodology that has been implemented includes a reorganization of the course and the application of the ECTS credit system included in a Teaching Guideline, plus a new evaluation system that gives more importance to the work done by the student throughout the whole course.

#### 8.1.1 The ECTS credit system Guideline

With the goal of unifying the different university degrees within the countries of the European Union, it has been decided to establish the so called European Higher Education Area (EHEA) by the year 2010. This goal of unifying all the different degrees can be achieved through the implementation of the ECTS credit system in different European universities.

Each credit given through the ECTS credit system includes not only the hours spent in the classroom, as in the previous system, but the time spent on other activities needed to pass the course such as the hours studying at home, the time spent working on research papers, the hours spent in the laboratory and also exams and similar work. ECTS stipulates that the effort a student should make to get 1 credit should involve from 25 to 30 hours of work.

In Table 3 the activities that are required in the Electric Machines II class and the time spent to achieve them are displayed both in hours and ECTS credit units.

#### 8.1.2 The evaluation method

The new evaluation method encourages students to work throughout the whole term to the benefit of the learning process. Each student has two options to be evaluated:

1. ‘Continuous’ evaluation. The final grade (maximum 10 points) is obtained by adding:
  - the exam grade (up to 8 points over 10); and
  - the classroom grade. Up to 2 points (over 10)

Table 3. Electric Machines II distribution in ECTS credits

		Time spent					
	Technique	Classroom hours	Attendance hours out of classroom	Work factor	Personal student hours	Total hours	ECTS
Theory	Lecture	25	–	1.7	42.5	67.5	2.25
Case solving	Workshop	11	–	2	22	33	1.1
Seminar	Self-learning using multimedia teaching units	1	4	2	10	15	0.50
Lab	Experiment	8	–	0.5	4	12	0.40
Field trips	Visits to factories	–	2	–	0	2	0.07
Work in groups	Tutorials	–	1	–	0	1	0.03
	Bibliographic analysis	–	–	–	3	3	0.10
	Document presentation	2	–	–	6	8	0.27
Exams	Written exams	–	2	–	0	2	0.07
<b>Total</b>		<b>45</b>	<b>10</b>	<b>–</b>	<b>88.6</b>	<b>143.6</b>	<b>4.8</b>



of the final grade can be obtained by completing the following activities:

- Exam about the Extension of Asynchronous Machines and Transf. (up to 1 point). It is taken in the classroom at a date announced previously well ahead of time (approximately after the first month of classes). If this exam is passed, its contents are excluded from the final exam.
- Work in groups (up to 0.75 points). These are projects to be done in groups and their contents are designated by the professor. The presentations are done in class and all the members get the same grade.
- Handing in problems (up to 0.25 points). This is done individually by each student and it has proved to be extremely effective in promoting and guiding the daily learning of the subject.

2. 'Conventional' evaluation. The final grade will be the grade of the final exam.

Passing the laboratory practice is compulsory with both evaluation methods.

### 8.3 Implementation of the new method

The new method has been introduced gradually over three consecutive academic years and at the end of each year the students' opinion about the modifications that have been made has been sought.

#### 8.3.1 Implementation phases

The new teaching methodology project that has been presented in this paper was introduced during the academic years 2004–05, 2005–06, 2006–07 and 2007–08, with small differences made between them as new teaching material has been gradually introduced. The steps taken each year since 2003 to teach Electric Machines II are outlined below. This information gives a better understanding of the outcomes:

- *Year 2003–04.* Before the implementation of the new teaching methodology the class was taught in the traditional way: lectures, laboratory sessions and the handing in of exercises individually completed by the students.
- *Year 2004–05.* In addition to the previously mentioned teaching tools, the electronic self-learning text, *Extension of Transformers* was introduced. The final exam (up to 9.5 points) and the points gained from the problems handed in (up to 0.5 points) were used in the evaluation computation.
- *Years 2005–06, 2006–07 and 2007–08.* During these three academic years the new teaching methodology was fully implemented. The following teaching tools were used: lectures, electronic self-learning modules dealing with Transformers and Asynchronous Machines, group work, laboratory sessions and handing in of solved problems. The evaluation method used is exactly the same as that presented above.

#### 8.3.2 Acceptance level

With the aim of detecting any deficiencies that the new proposed methodology may have, a 'final course evaluation' was given to the students and was answered anonymously by them at the end of the course. This questionnaire aimed to find out the students' opinion about the self-learning e-tool, the problems done in the classroom or at home, the work done in groups and the laboratory sessions. The last question was:

'Finally, do you think the different tasks carried out to improve this class (HTML file, work done in groups, problem solving, etc.) used this academic year have brought benefits to your learning? (disagree) 1, 2, 3 4, 5 (fully agree)'.

The results obtained from this last question are shown in the graph in Fig. 5.

In general, we can say that the new teaching system has been accepted well by the students, who have considered it to be positive from their own learning point of view. It must be mentioned that a better result from the evaluation was obtained after the third year, which implies that, once the initial reticence is overcome, most of the students have clearly adopted this new teaching methodology.

#### 8.4 Re-evaluating the new system outcome

It's expected that the new proposed teaching methodology benefits the students learning process even though this is very difficult to quantify. The only way of evaluating the benefits and improvements achieved by the implementation of this new teaching methodology is to compare the final grades in the two previous years before the implementation of the new methodology with those obtained afterwards.

In Fig. 6, the distribution of students, the number of students who took the final exam, and the numbers passing the class over the last four academic years are presented:

The data given in Fig. 6 will make more sense if it is analyzed by looking at the percentage values. The 'drop out rate' is defined as the difference in the number of students who were not present during the final exam and the number originally

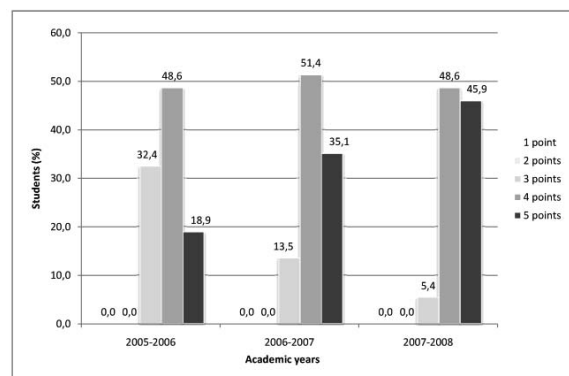


Fig. 5. Students' evaluation of the new teaching system.

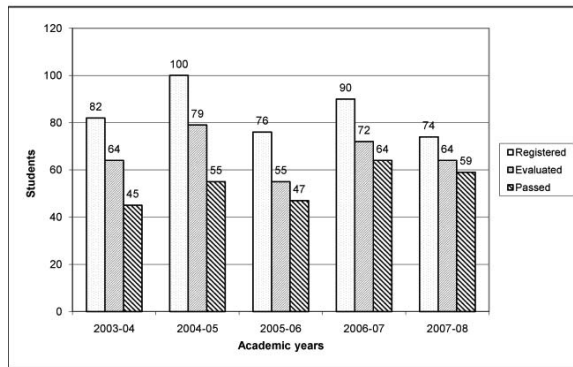


Fig. 6. Comparison between students registered, taking the exam, and passing.

Table 4. Evolution of the results obtained in the last four academic years

Academic year	Drop out rate (%)	Success rate (%)	Average grade
2003-04	21.9	70.3	6.2
2004-05	21.0	69.6	5.9
2005-06	27.6	85.5	7.1
2006-07	20.0	88.9	6.8
2007-08	13.5	92.2	7.7

registered during the specific academic year. The 'success rate' refers to the mean between the students who pass the class and the ones who took the final exam. In Table 4 these are shown plus the average grade in the specific class during specific academic years.

With these data, it can be observed that the 'drop out rate' has been reduced 13.5% over the three academic years that the new teaching methodology has been used and that both the 'success rate' (92.2%) as well as the average grade (7.7) have increased compared with the academic years when the new methodology was not in use (2003-04 and 2004-05).

It is important to point out that there was an increase in the 'drop out rate' after the first year that this methodology was implemented (2005-06). This increase suggests that there was some lack of confidence in the new methodology from the students' viewpoint. Also, Fig. 6 shows that there was less acceptance of the new methodology during the first year than in the second and the third ones. This 'drop out rate' did not affect the 'success rate', which increased, nor the average grades, which were higher than those of the previous academic year. The grade increase can

be explained by looking at the increased number of students who dropped out from the class because they feared a lower grade.

These data show, without any doubt, that the new teaching methodology has been more positive and productive than the previous teaching system.

### 8.5 Students' commitment

The data have demonstrated that the implementation of this new teaching methodology improves academic expectations, but in order to better evaluate the effectiveness of the new methodology, it would be necessary to analyze whether the goals achieved in this class are obtained within the time that the students are expected to spend on them.

To accomplish this, it was decided to include some specific questions dealing with the students' commitment to the specific class in question in the 'final evaluation of the course'. The results have shown that in the academic years 2005-06, 2006-07 and 2007-08 there was a commitment of 151.7 hours, 141.9 hours and 145.1 hours respectively. These number are in perfect agreement with the theoretical hours (143.6) shown in Table 3. From these results, and taking into account the existing uncertainty in the students' answers, it can be concluded that the number of hours needed to pass the class with the proposed new methodology fits adequately to the theoretical hours fixed by the ECTS credit system. It can also be observed that in the second year of the implementation of this new methodology, the students, having some reference from the previous year, have needed fewer hours of commitment to the specific class.

Finally, once it has been checked that the student contact hours correspond with those established in the new ECTS structure, a comparison of the student contact hours outside of the classroom between the new course and the old one should be made.

Before making this comparison, there are two aspects that need to be considered:

- The contents of the subject Electric Machines II (6th semester in plan 2000) correspond to the contents of half of the 10th and the 11th semesters in the old curriculum (Plan 76). In order to be able to make this comparison, the total hours have been divided by the number of semesters.
- The old plan only dealt with the classroom hours in every course. Since the classroom hours and the hours in the laboratory are taught in a similar way in both plans, it is possible to apply the same work factors defined in Table 3.

Table 5. Student contact hours out of the classroom in Plan 76

Semester	Lecture hours	Practice hours	Lab. hours	Contact hours out of classroom
½ 10th	30 × 5/6	15 × 5/6	10	$(30 \times 5/6 \times 1.7) + (15 \times 5/6 \times 2) + 10 \times 0.5 = 72.5$
11th	50 × 5/6	25 × 5/6	16	$(50 \times 5/6 \times 1.7) + (25 \times 5/6 \times 2) + 16 \times 0.5 = 120.5$

Taking into account that the classroom sessions last 50 minutes each, according to Table 1, in Table 5 the total student contact hours per semester is shown.

## 9. CONCLUSIONS

Influenced by the surrounding atmosphere with new study plans in a process of change and the implementation of new teaching methodology, the Group of Educational Innovation in Electric Machines (GIEME) has taken a series of measures in order to facilitate the students' learning process of the basic contents of electric machines.

In the specific case of the course 'Electric Machines II' a new teaching plan based on ECTS credits with a new evaluation system has been proposed. The teaching system is based not only on class lectures but it also includes a series of activities carried out by the students throughout the academic year, such as problem solving seminars, teamwork, etc., which help to guide and aid their learning process. The evaluation system has changed format so that the students' work will carry 20% of the final grade, which can be seen as an incentive for the students to learn and get an improvement in the final grade.

In order to establish this new teaching methodology it has first been necessary to develop a

series of support tools, such as a textbook for the class, some units of multimedia self learning and a series of specific guidelines for carrying out research work in groups, measures that have been positively received by the students.

Finally it is necessary to emphasize that in order to carry out the established teaching methodology, it has been of vital importance to rearrange the teaching in the lab, where new practice guidelines have been produced, new workbenches have been developed and the experiments have been automated as far as measuring and calculation of results, thus creating an atmosphere conducive to the students' self learning.

With the introduction of this new teaching methodology, remarkable results in student academic achievement have clearly been obtained. First, the number of students who have taken this subject has increased, thus reducing the drop out rate from 21.95 to 13.5%. Secondly, the number of students who have passed the subject has increased, achieving a success rate of 92.2% (from 70.3%). Moreover, these students have achieved a better grade, increasing the average grade from 6.2 to 7.7. All these improvements in the academic performance have been achieved with a number of hours of student work that fits with the ECTS credit system defined in EHEA (145.1 real hours versus 143.6 theoretical hours).

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