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A Power Electronics and Drives Curriculum with Project-oriented and Problem-based Learning: A Dynamic Teaching Approach for the Future

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ABSTRACT

Power electronics is an emerging technology. New applications are added every year as well as the power handling capabilities are steadily increasing The demands to the education of engineers in this field are also increasing Basically the content of the curriculum should be more expanded without extra study time This paper present a teaching approach which makes it possible very fast for the student to get in-depth skills in this important area which is the problem-oriented and project-based learning. The trend and application of power electronics are illustrated The necessary skills for power electronic engineers are outlined followed up by a discussion on how problem-oriented and project-based learning are implemented A complete curriculum at Aalborg University is presented where different power electronics related projects at different study levels are carried out

Keywords: Power electronics, Problem-oriented and Project-based Learning

1. Introduction

Education both during ordinary graduate studies and through life-long learning becomes still more important. The technological progress is faster than ever and the "life-time" of a new education is becoming shorter and shorter. In some emerging technology areas the lifetime is less than three years However, basic skills like mathematics, physics and related technical disciplines are still important as well as skills like communication (written and orally), teamwork, project organization and management are becoming more and more useful skills

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One of the emerging technologies where a continuous update of the curriculum is essential is power electronics and its applications[1][2] Application-wise power electronics is expanding its use and technology-wise a number of technical disciplines is necessary to be updated steadily. The area needs a basic understanding of classical fields as well as a good knowledge to the system it is used in. Furthermore, the fields are characterized by that practical skill are important in respect to understanding and test

Different approaches may be taken to teach future engineers in this emerging technology A majority of universities are using a classical approach where the students by a huge amount of courses and one or two small projects obtain a Masters degree when the exact number of credits is obtained This may give the student a very good knowledge to individual disciplines while mixing the disciplines together are difficult as well as the practical skills are not really complete. An alternative approach is to focus more on project-based learning either by the individual it-self or by working in teams in order to extend the curriculum to other professional skills than the technical matters[3] Some universities have introduced this approach to a more or less extent and this paper will describe an approach where project-oriented and problem-based learning is introduced from day one the student starts and the method has been proven to work successfully in more than twenty years[4]-[10]. It has turned out to be a very efficient approach in power electronics and drives curriculum because it can give the students all necessary skills the industry and the research institutions are asking for This paper will first describe the trends in the power electronics technology including which areas may be important in the future. Next, the needed skills for a power electronic engineer are discussed. The implementation of project-based and problem-oriented learning is further described as well as the power electronic and drives curriculum using this concept is introduced

2. Power Electronics Technology

The power electronic technology is moving rapidly. Two factors are the primary movers The first one is the development in microprocessors, which steadily opens new possibilities for applications but also for the design methods

The second area is the development in power semiconductor devices both in respect to cost but also in respect to the performance obtained for the same area of silicon in the power device. The main goal of the power electronics technology is to convert electrical power from one stage to another as efficient as possible with a high level of intelligence. In order to cover the technology in a competitive matter Fig 1 shows the fundamental and the inter-disciplinary technical fields, which are of importance

As it can be seen in Fig 2 the power electronic technology is used in production, transmission and the use of electrical energy Furthermore, it is used in autonomous systems like cars, satellites, airplanes etc.

The turnover in the power electronics industry is steadily growing and there are a number of prime movers to extend the use of power electronics.

The prime movers in the recent years have been communication technology, automation and energy saving but for the moment a significant rise in distributed power/renewable energy and appliance industry is going on In a longer term the transportation area will be important Fig 3 shows ten important prime movers in the power electronics in history.

A curriculum in this area should both cover all the technical disciplines and introduce the applications. The first can especially be done by courses and the latter by project work

Power Electronics Technology Disciplines	
Fundamental fields	**Interdisciplinary fields**
• Device technology • Energy technology • Circuits • Power Systems • Magnetics • Electronics • Electrical Machines • Control • High Voltage • EMC	• Thermal management/cooling • Reliability • Prototyping • Modeling and simulation • Production technology • IT (Embedded system) • Optimization • Materials

Fig 1 Overview of disciplines necessary in the power electronics technology

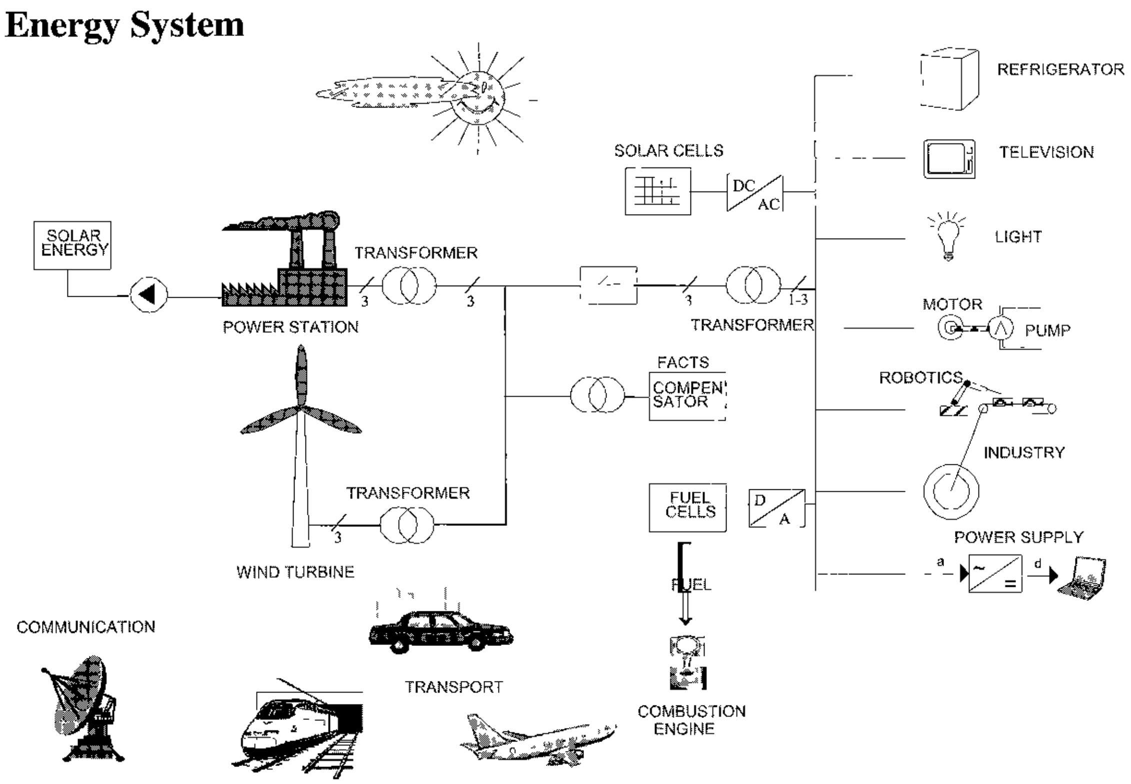

Fig 2 Energy system where main applications for power electronics are identified

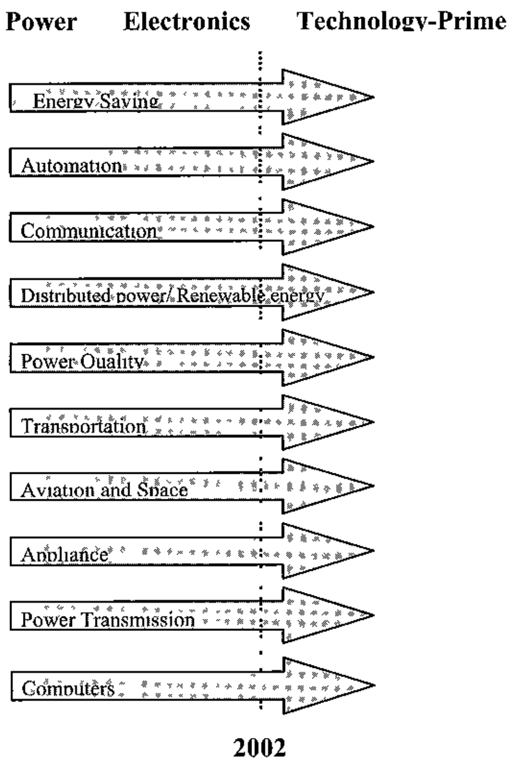

Fig 3 Prime mover areas using the power electronics technology

3. Problem-oriented and Project-Based Learning

The organisation of problem-oriented and project-based learning is that the students use half of their study time making projects and half of the time is taking courses Half of those courses are study-unit courses, which give the students basic knowledge and the other half of the courses are project-oriented courses, which support the project Study-unit courses are typically examined

One project is carried out at each semester In their final project (thesis) the students spend all the time on the project work. Normally 6 students work together in a project group except for their Bachelor or Master project, where normally only two students work together

Each project group has during their project a supervisor who is a member of the faculty and the supervisor is also an active researcher The project group requires a room at the university where they can work with their problems in connection with their projects, meet their supervisor and solve specific problems related to the courses/lectures. A typical day for the student is divided into two halves with lectures and tutorials from 8 00 to 12 00 and project time from 12 30 to 16 30 This means that the students during their study are present almost all the time at the university.

Each semester has a specific theme and project titles address problems related to this theme The academic staff and industry make proposals to a particular semester The proposals are at the higher semesters (graduate) mostly related to the research interest or initiated by the industry. The way to implement problem-oriented education is shown in Fig 4.

Given a problem at a semester the students first make a problem-analysis, limit the project and they make a time and working plan After that they do the problem solving by the use of literature, lectures, group studies, tutorials, field-work and experiments During the project work the students have regular meetings with a supervisor (weekly). Each semester is divided into four periods of five weeks (see Fig. 5). In the first period the students have a high number of lectures and they spend some time on defining the problem in their project and they are also doing some literature search. Typically within three weeks a problem definition and a time/working plan are defined and from that the students solve the problem Less lectures are present in the second period In the third period almost all time is spent on the project work At a specific date defined by the study-board the project group delivers a report (50 pages 6 200 pages) on their project work Two-three weeks later the group is examined groupwise and they get an individual mark. At the examination each student makes also an individual presentation of a topic related to the project and they all have to answer questions concerning the whole project-report and the related

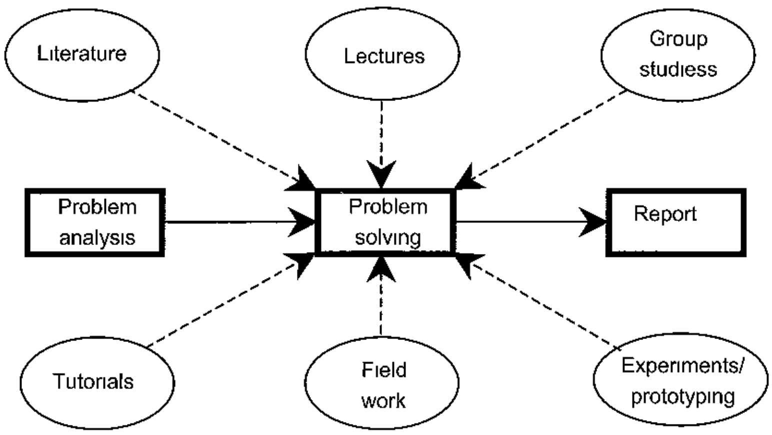

Fig 4 Implementation of problem-oriented and project-organised education

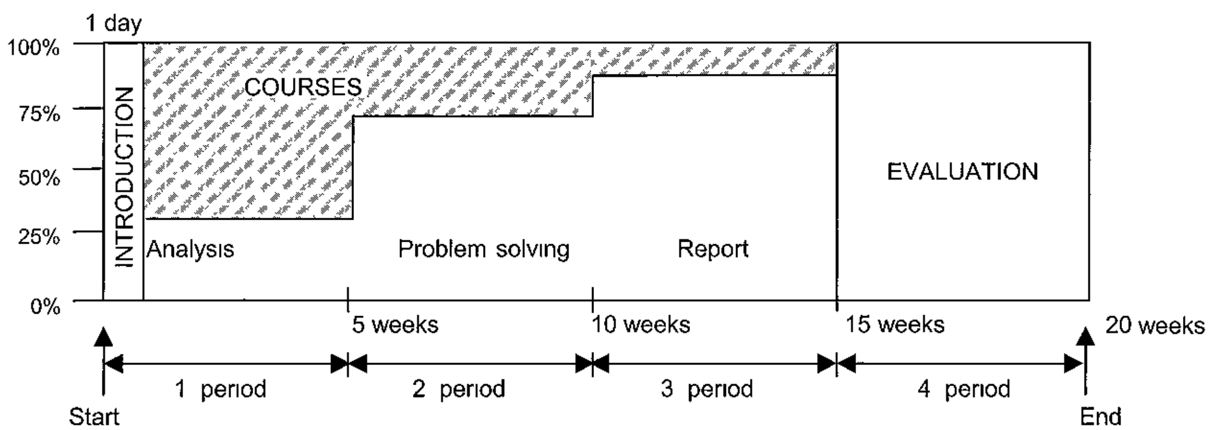

Fig 5 Typical distribution between courses and project work during one semester

courses Fig. 5 illustrates the time spent on courses and project work during one semester

One semester is divided into 30 ECTS-units (European Credit Transfer System), which include the total time spent on project work and courses An ECTS is for the student equivalent to 5 half days at the university plus time for preparation So, a course with one ECTS contains 5 lectures (typically two hours each), with exercises (two hours additional)

A typical faculty member spends 50% of his time on teaching, 40% on research, and finally 10% on administration The teaching includes both courses and project supervision The faculty member will receive 70 hours for a course of one ECTS. This corresponds to 8% of the full working time. Supervising one project counts for 100-130 hours So, to fulfil the total teaching obligations the faculty member has to do 5-6 ECTS of courses or to supervise 3-4 projects A mix between the two possibilities is most likely.

4. Curriculum in Power Electronics and Drives

The curriculum in Power Electronics and Drives at Aalborg University is implemented based on problem-oriented and project-based learning. It has during the years dynamically undergone changes

Today, the students start with a basic year (2 semesters) in Electrical Engineering. Then they spend three semesters working with Electrical and Electronic Engineering. After that they continue with one year in Electrical Energy Engineering and finally they enter the M Sc program in Power Electronics and Drives for 1½ year The last three semesters are completely taught in English. In order to enroll foreign students into this study approach an introductory semester is offered where focus is on problem-based learning Fig 6 shows the overall structure of the study

The students can decide to leave the whole study after 3½ year and then they get a B Sc in Electrical Energy Technology The students may get 30 ECTS pr. semester if they pass all examinations The courses offered through the study are varying a lot. In the beginning they are more general while at the end of the study the courses are more specialized to power electronics and drives Fig 7 shows an overview of the offered courses during a whole five-year study programme where also the distribution between project work and courses are shown

As it can be seen the students can during a whole study obtain many credit units in the power electronics and drives area if they decide to work with that on all the project during the study

As stated earlier every semester is finalized by a report, which is defended At the 7'th semester the report is

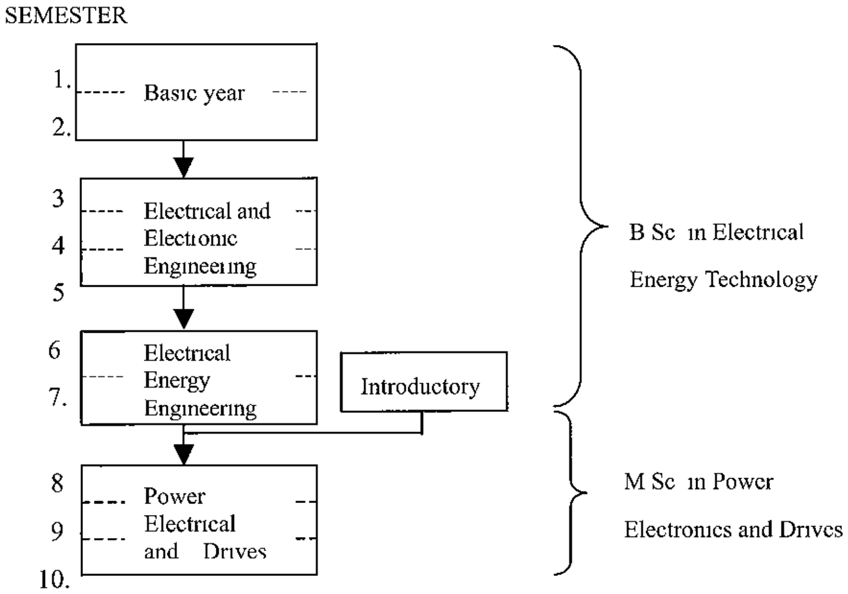

Fig. 6 Power electronics and drives curriculum organization at Aalborg University

		Semester										ECTS credits
		1	2	3	4	5	6	7	8	9	10	Total
1	Electro-physics		2	3	2							7
2	Fundamental Electrical Engineering		1	6		2						9
3	Power Systems			1			2	1		1		5
4	High Voltage Techniques							1	2	2		5
5	Power Electronics					1	2	2	1	3		9
6	Electrical machines and drives					1	2	2	3	2		10
7	IT (embedded systems etc)	1			7	3			1			12
8	Control			1		1	3	1	3			9
9	Project work in the power electronics and drives area	15-0	15-0	15-0	15-0	18	17	18	18	22	30	123-183
Sum						26	26	25	28	30	30	189-249

Fig 7 Offered courses and project time in the main areas of the power electronics and drives curriculum

substituted by writing a scientific paper, making a poster including presentation and some supplementary documentation. A small workshop is also held at the end of the semester for all students where they basically learn to participate in a conference

As seen in Fig 7 the total sum in each semester is not 30 ECTS because courses are offered which are not directly related to power electronics and drives. At the lower semesters e g. mathematics, social science and IT courses are offered Fig 7 shows also that the project work may be related to power electronics and drives or not at the low semesters, because the students can select project as they may wish from a project catalogue, which is related to a project theme

Fig. 8 shows the title of the themes for a five-year study at Aalborg University in power electronics and drives.

As it can be seen in Fig 7 and Fig. 8 the power electronics and drives specialization will appear mostly in the last part of the study

5. Master Program in Power Electronic and Drives

As shown in Fig. 6 and Fig 8 the last three semesters are dedicated only to power electronics and drives. The two first semesters combine courses (40%) and team-based project work (60%), while the third semester is dedicated exclusively to the Master's thesis Important technical fields, such as power semiconductor devices, power converters, modelling, electric machines, drives and control, are taught in a number of courses.

In the project work, focus is put on prototyping and experimental work which are carried out in the laboratories with access to computers, acquisition systems, digital signal processors, electronic components, etc Prior to the first semester, an introductory semester (see Fig. 6) is offered to all foreign students. This has been highly recommended in order to learn about problem-based learning.

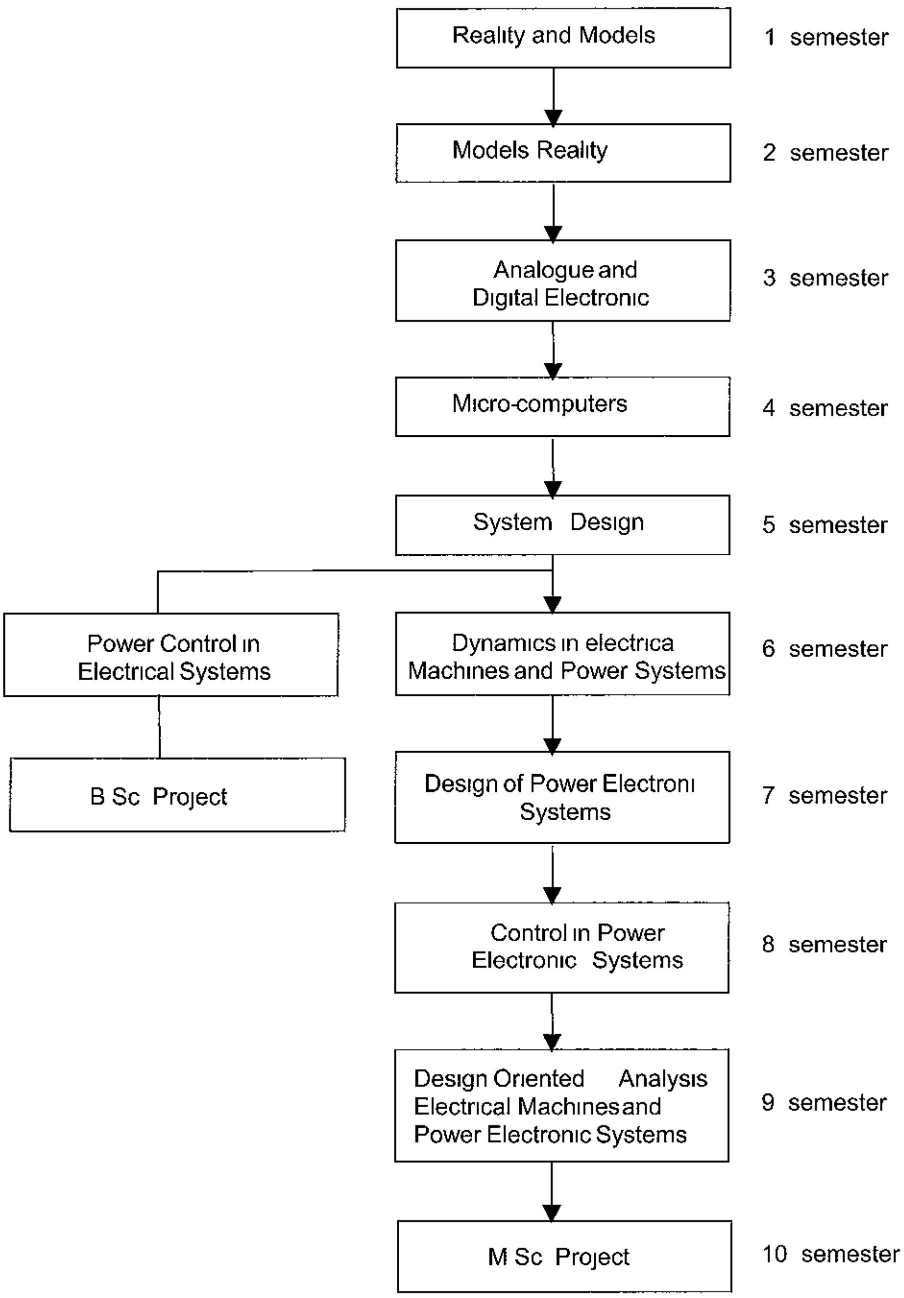

Fig 8 Project themes during a complete study in power electronics and drives

In special circumstances it may be possible to begin the study without taking the introductory semester

5.1 Introductory semester

The introductory semester is offered to foreign students accepted into the various master programmes The introductory semester is intended to provide students with comprehension and understanding of the problem-based learning method, which is being used at Aalborg University

It also intends to give students experience with project work in connection with problems within their areas, together with the corresponding documentation (report writing)

5.1.1 1st semester (8'th semester) Control in Power Electronics and Drives

The theme of the first semester is modelling, simulation and digital control of an electrical system including a power electronic converter. The semester gives an overview of complete power electronic systems and their dynamics as well as hands-on in real-time implementation in digital signal processors is provided. The interaction between the different parts of the electrical system is also studied and synthesized.

5.1.2 2nd semester (9'th semester) Design-oriented Analysis of Electric Machines and Power Electronic Systems

In this semester focus is on analysis and modelling of power electronic systems, electric machines or drives in order to optimise one or more performance parameters, e.g. efficiency, system response or the number of components used in a power converter. Special emphasis is also put on building a real prototype of e.g. an electric machine or building a complete power electronic converter with a detailed test.

5.1.3 3rd semester Thesis in Power Electronics and Drives

In the final semester a completion of the master's thesis is made combining the skills learned in the first and second semesters. Emphasis is put on combining system knowledge, modelling and simulation with a realization/validation of a prototype. All projects are industrially related, and most often a close collaboration with a company is established. All the time is dedicated to the master's thesis, which is normally four months of full-time work.

In the master program state-of-the-art teaching facilities are used in the courses like DSPACE-systems for drives and control[8]-[10] as well as building-block approaches are also introduced[9] as much as possible.

Fig. 9 gives an overview of the M.Sc. programme in Power Electronics and Drives.

	1st semester	2nd semester	3rd semester
Courses	• Power converters (AC/DC, DC/AC) • Brushless machines • Control of AC machines • Control of brushless machines • Modelling of power converters • High voltage techniques • Optimal and adaptive control • Digital ASIC	• Resonant converters • Advanced control of PWM inverter-fed AC machines • Computer-aided engineering in power electronics and drives • Loss functions in electric machines • Local compensation and FACTS • Design of electric equipment • Switched mode power supplies • Power semiconductor devices and their models	
Project examples	• Resonant converters • Control of permanent magnet motor drives • Optimal power point tracking in grid connection solar cells • Variable speed control of wind turbines • Control of battery charger	• Modelling of iron losses in Electric machines • Design of an electronic ballast • Power converter for uninterruptible power supply • Energy-optimised control of an induction motor • Switched mode power supply for a computer	• Multi-level converter for static VAR compensation • Soft switching converters for green power applications • High frequency modelling of an adjustable speed drive • Sensorless control of a compressor for refrigeration • Design of a switched reluctance motor

Fig. 9 M.Sc. programme in power electronics and drives at Aalborg University and taught in English

6. Conclusion

The project-oriented education structure offers a number of advantages. It is very easy to control the learning process, what the students are learning and how they are learning it.

That also means rapid changes can be done in the curriculum in an emerging field like power electronics and drives. The formulation and the content of the projects are extremely important. That is the amplifier of the intentions for every semester and for the whole study.

The project-organized education can be regarded to be a complement to the conventional system for teaching. The graduates produced are more readily adaptable for research and for industry, and thus more directly employable. On the other hand, the graduates coming from a more traditional system are perhaps better grounded in fundamentals and are more capable of working independently although in general they will require more on the job training.

A comparison with universities with conventional education says that the yield is much higher at Aalborg University. The main part of the students graduates at the described time and more than 80 % of the students in engineering pass their examinations in time. Finally, a recent investigation on the strength of the system former students satisfaction of studying at Aalborg University emphasized the strength of the system. More than 95% of all former students would take the same university and curriculum if they got a new chance to do their study. Further information can be found at [11].

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He is involved in more than fifteen research projects with the industry He is the author or co-author of more than 250 publications in his research fields

Dr Blaabjerg is associated editor of the IEEE Transactions on Industry Applications, IEEE Transactions on Power Electronics, Journal of Power Electronics and of the Danish journal Elteknik

He received the 1995 Angelos Award for his contribution in modulation technique and control of electric drives, and an Annual Teacher prize at Aalborg University, also 1995 In 1998 he received the Outstanding Young Power Electronics Engineer Award from the IEEE Power Electronics Society He has received four IEEE Prize paper awards during the last four years