ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 *2010. No. 10(106)*
ELEKTRONIKA IR ELEKTROTECHNIKA

EDUCATION IN ELECTRONICS AND ELECTRICAL ENGINEERING
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Electrical Engineering Curricula – An Example of a Post-Bologna Master Course

F. Lopes
Instituto Superior de Engenharia de Coimbra,
Rua Pedro Nunes, 3030 Coimbra, Portugal, phone: 239790200, fax: 239790321, e-mail: flopes@isec.pt,
Instituto de Telecomunicações - Pólo de Coimbra, Pólo II da Universidade de Coimbra, 3030 Coimbra, Portugal

Introduction

Sustainable progress in modern societies imposes very demanding requirements for the production structures that can be summarized in the need for very high levels of scientific and technical expertise, supported by a strong ethic background. Production, competition, quality, efficiency and creativity are key characteristics required for successful enterprises in the increasingly global world. To pursue these objectives, there is the fundamental need for the combination of advanced technologies with highly qualified and highly motivated human resources. Thus, it is of paramount importance the qualification of individuals with a high level of scientific, technical and cultural education, while demonstrating strong critical analysis and innovation abilities.

In this context, the *Instituto Superior de Engenharia de Coimbra (ISEC)* proposed in 2006 a master degree in Automation and Communications in Energy Systems [1, 2]. It consists on a transversal specialization in the electrical engineering area, integrating and interconnecting, scientifically and in an industry oriented profile, the Automation, Energy Systems and Communications areas. These are the basis areas for the First Cycle degree in Electrical Engineering [3] and correspond to reference areas in the European High Education Area [4].

Global Objectives

The proposed degree programme objectives, acquired competences, structure and organization, followed the Portuguese Law [5], the main principles of the Bologna Process [6] and the recommendations from national and international engineering councils.

The proposed master was also supported by the large experience in engineering education at ISEC, in both three years and five years degree programmes, which has been enjoying high recognition from the employment market and industry partners.

The explicit definition of objectives in higher education is a requirement of Portuguese Education Basis Laws, which include main global objectives [5]. These global objectives are based on those set for the Bologna Process [6], which represents a new education paradigm in the European High Education Area. It promotes the transition from a knowledge transmission based system to a competence development based system. This principle also represents a European approach to the need for the definition of new development models. It proposes answers for present high education challenges such as competence acquisition, mobility, employment, universality and life-long learning.

Based on the Dublin Descriptors, and as stated in Portuguese Law: *Artigo 15.º, Decreto-Lei 74/2006* [5], global objectives can be shortly described as follows: second cycle programmes build on the knowledge, skills and conceptual understanding acquired in first cycle programmes. They further develop the ability to independently apply knowledge, deal with new and complex problems, issues and situations, and to acquire the skills for future careers in the professional industry world, research institutions or academia. Students awarded with a master degree are also expected to have good communication skills and the ability to evaluate ethic responsabilities associated with engineering solutions. In addition, Portuguese Law states that, for Polythechnic Schools such as ISEC, a master degree shall provide the student with a high industrial profile specialization .

The Automation and Communications in Energy Systems master, aims to provide a high quality degree, specially oriented for the professional environment in the electrical engineering area. It is organized in order to develop competences with high potential for the national and European grows, for the development of applied knowledge, and for the generation of high value in industry and institutions. The graduated students should be able to develop their professional activities with a high level of scientific and technical competence, as well as with high responsibility in the technical, ethic and social domains.

Degree Profiles and Competences

Electrical Engineering is a reference engineering area, fundamental for global sustainable development and for the quality of life in modern societies. On the one hand, it is a wide area of knowledge, requiring some level of specialization in order to allow one individual to acquire enough competences, needed for application in new and complex situations, encountered in a given area of the industrial activity. On the other hand, the excess specialization usually results in the loss of the ability to understand wide-area problems, which are mostly multidisciplinary, thus requiring a detailed understanding of several specific subjects. In this proposal, the areas of Automation, Energy Systems and Communications are used as basis components, defining an education profile for competences in a class of world systems in the electrical engineering area. These basis areas are ubiquitous areas, extensively present in all modern technological systems. They are fundamental in energy and production systems, transportation, services and buildings. Thus, there is a fundamental need for professionals that can design, develop and maintain these high complexity systems. Moreover, communication technologies are paramount in production structures, which are increasingly distributed in terms of the resources, the applications and the users, requiring efficient monitoring, decision and control.

The proposed master degree integrates the Automation, Energy Systems and Communication areas in a coherent framework, to create a study profile specially oriented to the present development needs of the industry and organizations. Two transversal Specialization Areas in the electrical engineering domain were proposed:

- Energy and Automation Systems;
- Industrial Systems.

The "Energy and Automation Systems" Specialization Area integrates the Energy, Automation and Communications basis areas in a profile that targets competences in the production, distribution and management of energy, allowing the analysis and intervention in electrical energy and renewable energy systems, as well as in the environmental aspects of the production, distribution and utilization of energy. This profile includes specialized courses in the areas of energy systems, renewable energies, environmental management, electrical vehicles and energy markets. The "Industrial Systems" Specialization Area integrates the basis areas in a profile that targets competences for integrated automation and communication solutions in the industry and organizations. It includes subjects such as robotic systems, industrial networks and integration of industrial systems, mobility and wireless communications, as well as industrial computer vision and multimedia. Both profiles include common specific courses in engineering mathematics, automation and control systems, applied information technologies, building automation technologies and corporate management.

In order to develop the degree curricula and to achieve the proposed objectives and profiles, two sets of specific competences, to be acquired by the students when completing each of the specialization areas, were defined. The competences were defined considering the second cycle Dublin Descriptors, the ABET criteria, the recommendations from engineering councils, as well as the school teaching and industry experience. Table 1 presents the competences, the specialization area where they apply and the specific course units most associated with their acquisition. The set of chosen course units with syllabus and organization tailored for the defined objectives and competences are shown in Table 2.

Structure and Organization

The programme structure is based on reference European experience and target compliance with the defined objectives and competences. It is organized in 4 semesters, corresponding to 120 ECTS (European Credit Transfer System). It assumes a first study cycle with 180 ECTS, resulting in an accumulated engineering education of 5 years or 300 ECTS. This is a reference study effort for professional organizations to recognize the individual ability and responsibility to intervene in most engineering activities. The master programme is composed of a Specialization Course, which integrates a set of course units representing 55% (66 ECTS) of the total number of credits, and an Industry Internship with a Final Report, or an Original Project, specially prepared for this purpose, that represents 45% (54 ECTS) of the total credits. This structure was set according to *Dec.-Lei n.º 74/2006* [5], which also allows the awarding of a Specialization Diploma to students concluding the Specialization Course. The course units are shown in Table 2 including course classification, specialization area, attributed ECTS, semester organization and semester contact hours.

Based on legal recommendations, a unit ECTS was associated with 26 student work hours, in a total annual of 1560 hours spread over 40 working weeks. In each semester 14 weeks are reserved for classes, 1 for student support and 5 for examinations. Course Unit Forms describing most operational aspects, including syllabuses, bibliography and ECTS allocation times, were defined in the proposal document for each course unit [1]. A large percentage of specific engineering and technology course units, coupled with a 54 ECTS industry internship or a project, guarantee a highly industrial profile. This profile is reinforced by a large number of laboratory classes (33% to 43% with 14 specialized laboratories available), and the regular organization of special-subject industry seminars.

Portuguese Law, reflecting a European Commission priority, promotes new opportunities for the individual access to higher education. This master, building on school experience, has been taught in an after-work schedule, allowing working professionals to attend, providing an industry oriented opportunity for life-long education [7].

Conclusions

The Automation and Communications in Energy Systems master, aims to provide a high quality degree programme specially oriented for the professional environment in the electrical engineering area and organized in order to develop competences with high potential for the national and European grows.

Table 1. Relationship between Competences and Course Units

Competence	Area	Course	Competence	Area	Course
To define, project , implement and maintain an information system including databases	EAS IS	AIS	To plan, operate and control electrical power systems in the market environment	EAS	EM
To project , implement and maintain an information transmission system	EAS IS	IEC	To conceive and implement security systems for electrical power networks	EAS	PSSC
To project , implement and maintain automation and control systems	EAS IS	ACS	To understand and to apply regulatory policies associated with the energy sector	EAS	EM, RE SDEM
To project , implement and maintain electrical installations in intelligent buildings and domotics	EAS IS	HAIB	To know the problems and solutions of transportation for sustainable mobility	EAS	ETV SDEM
To project , implement and maintain building communication networks	EAS IS	HAIB IEC	To know electrical and hybrid vehicle technologies for road rail and marine applications	EAS (SI)	ETV (MEA)
To know and understand economy mechanisms, companies and consumer behaviour	EAS IS	CM	To project and simulate simplified systems for electric traction and electrical vehicles	EAS (SI)	ETV (MEA)
To apply techniques for analysis and management in companies and organizations	EAS IS	CM	To conceive and install robotic systems	SI	RS
To evaluate investment projects, budgets, supervise and manage works	EAS IS	CM	To conceive and implement distributed systems based in microprocessors	SI	DIS IEC
To promote innovation, research and technology development in the Specialization Area	EAS IS	All CSP	To conceive and implement distributed instrumentation systems	SI	DIS
To plan, coordinate and execute projects and work programmes	EAS IS	All CSP CC	To know, project, implement and configure systems for the presentation and distribution of audiovisual multimedia contents	SI	CVM
To promote enterprising in industry and organizations	EAS IS	All CSP CC	To conceive and implement techniques for the programming of integrated systems	SI	DIS AIS
To follow and supervise works in the Electrical Engineering Specialization	EAS IS	All CSP CC	To plan and manage transport and access networks and to analyse tariffs	SI	WCM IEC
To project and implement quality improvement programmes	EAS IS	All CSP CC	To select and use available technologies for local and industrial networks	SI	IEC
To devise new techniques for higher company efficiency and competitiveness	EAS IS	All CSP CC	To conceive and implement communication and mobile systems based on wireless technologies	SI	WCM
To project, implement and maintain production systems based on renewable energies	EAS	RE SDEM	To project and dimensioning electric motor systems, to know and to use electrical machines control systems	SI	EMA
To conceive, develop and implement environmental management systems	EAS	SDEM	To develop software interfaces for the command of electrical machines	SI	EMA
To know, implement and maintain power systems supervision and control systems	EAS	PSSC	To conceive, install and maintain industrial vision systems and to integrate audiovisual communication systems	SI	CVM
To evaluate consequences and conceive solutions for the problems with the integration of renewable energies in power systems	EAS	EM PSSC RE	Area : Specialization Area Course: Course Unit	---	---

Table 2. Main structure of the degree programme

Course Unit	Area	Classification	ECTS	Year/Semester	Semester contact hours T / TP / PL / TU / S
Engineering Mathematics (EM)	EAS and IS	BS	6	1st / 1st	28 / 14 / 14 / 0 / 0
Applied Information Systems (AIS)	EAS and IS	SC	6	1st / 1st	28 / 0 / 28 / 0 / 0
Industrial and Enterprise Communications (IEC)	EAS and IS	SC	6	1st / 1st	28 / 0 / 26 / 0 / 2
Automation and Control Systems (ACS)	EAS and IS	SC	6	1st / 1st	28 / 0 / 26 / 0 / 2
Home Automation and Intelligent Buildings (HAIB)	EAS and IS	SC	6	1st / 1st	28 / 0 / 28 / 0 / 0
Renewable Energies (RE)	EAS	SC	6	1st / 1st	28 / 24 / 0 / 0 / 4
Energy Markets (EM)	EAS	SC	6	1st / 1st	28 / 12 / 12 / 0 / 4
Power Systems Supervision and Control (PSSC)	EAS	SC	6	1st / 2nd	28 / 0 / 28 / 0 / 0
Electric Traction and Vehicles (ETV)	EAS	SC	6	1st / 2nd	28 / 0 / 28 / 0 / 0
Sustainable Development and Environmental Management (SDEM)	EAS	SC	6	1st / 2nd	28 / 24 / 0 / 0 / 4
Robotic Systems (RS)	IS	SC	6	1st / 2nd	28 / 0 / 26 / 0 / 2
Distributed Industrial Systems (DIS)	IS	SC	6	1st / 2nd	28 / 0 / 28 / 0 / 0
Electric Machines Applications (EMA)	IS	SC	6	1st / 2nd	28 / 0 / 28 / 0 / 0
Wireless Communications and Mobility (WCM)	IS	SC	6	1st / 2nd	28 / 0 / 26 / 0 / 2
Computer Vision and Multimedia (CVM)	IS	SC	6	1st / 2nd	28 / 0 / 26 / 0 / 2
Corporate Management (CM)	IS	CC	6	2nd / 1st	28 / 28 / 0 / 0 / 0
Project or Internship (PoI)	EAS and IS	SC	54	2nd / 1st and 2nd	0 / 0 / 0 / 45 / 0
BS: Basis Sciences, SC: Specialized Sciences, CC: Complementary Sciences T: Theory, TP: Theory-Practical, PL: Pratical and Laboratory, TU: Tutorial, S: Seminar					

The proposed master is further oriented for the development of applied knowledge, and for the generation of high value in industry and institutions. The structure and organization target the compliance with the Dublin Descriptors and the recommendations from national and international professional organizations. The high industry profile and the after-work schedule make this master a unique opportunity in the national education offer. The duration and contents of the programme provide Portuguese students similar education, mobility, and professional opportunities as other students in the European High Education Area [8].

Graduated students should be recognized by the equilibrium between their scientific, technical and human education. This education should provide them the ability to develop successful engineering careers in the actual industrial context, as well as to adapt to future changes and to shape new developing paradigms. To guarantee continuous monitoring and quality, trusted accreditation entities must be present.

Acknowledgement

This paper is based on the master proposal document organized by a board coordinated by the author and further composed by Victor Santos, Paulo Pereirinha, Carlos Ferreira and Nuno Ferreira.

The proposal had also many contributions from other colleagues, especially from Dulce Coelho, António Campos, Inácio Fonseca, António Almeida and Verónica Vasconcelos by detailed proof-reading.

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Received 2010 05 29

F. Lopes. Electrical Engineering Curricula – An Example of a Post-Bologna Master Course // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 10(106). – P. 155–158.

A Post-Bologna Master in Automation and Communications in Energy Systems is presented, which aims to provide a high quality degree specially oriented for the professional environment in the Electrical Engineering Area. The structure and organization target the compliance with the Dublin Descriptors and the recommendations of national and international professional organizations. The master is composed of a Specialization Course, which has a set of course units representing 55% (66 ECTS) of the total number of credits (120 ECTS), and an Industry Internship, or an original Project, that represents 45% (54 ECTS) of the total credits. It has a highly industry oriented profile, and an after-work schedule. The 'Energy and Automation Systems' Specialization Area integrates the Energy, Automation and Communications basis areas in a profile that targets competences in the production, distribution and management of energy. The 'Industrial Systems' Specialization Area integrates the basis areas in a profile that targets competences for integrated automation and communication solutions in the industry and organizations. The master is specially oriented to develop competences with high potential for the creation of applied knowledge, and for the generation of high value in industry and institutions. Bibl. 8, tabl. 2 (in English; abstracts in English and Lithuanian).

F. Lopes. Elektros inžinerijos studijų programos įgyvendinimas Bolonijos universiteto magistrantūros strudijose // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 10(106). – P. 155–158.

Elektros inžinerijos krypties aukštos kvalifikacijos specialistai yra rengiami Bolonijos universiteto magistrantūros strudijose. Tai plačiausiai pramonės sektoriaus atžvilgiu orientuotos studijos. Studijų programa orientuota taip, kad studentai gautų didelį potencialą turinčių taikomųjų žinių, svarbių tiek pramonės, tiek mokslo prasme. Bibl. 8, lent. 2 (anglų kalba; santraukos anglų ir lietuvių k.).