Electric Power Engineering Education

By Gianfranco Chicco, Peter Crossley, and Carlo Alberto Nucci

©ISTOCKPHOTO.COM/NICOELNINO

Cultivating the Talent in the United Kingdom and Italy to Build the Low-Carbon Economy of the Future

Digital Object Identifier 10.1109/MPE.2018.2841458
Date of publication: 17 August 2018

CHANGES IN THE POWER-RELATED industrial and manufacturing landscape of Europe, the restructuring of utilities, and the drive toward a low-carbon economy require the education of engineers with a broader understanding of technology, social behavior, and economics. These men and women need enhanced knowledge and capabilities in leadership, human communication skills, data analysis, business management, and economics, in addition to the classical electrical engineering skills of

1540-7977/18©2018IEEE

In the era of smart grids, energy sustainability, and increasing environmental constraints, many opportunities are emerging for future engineers.

mathematics, circuit analysis, power systems, energy conversion, data communications, and signal processing, although these still remain the pillars of their education.

The need for this bundle of skills is also, in part, a consequence of power system evolution from a traditional structure standing on centralized generation and control, with customers supplied through ac transmission networks and distribution feeders, to a new structure—the smart grid—in which significant renewable generation is located at the distribution level and operates through dc/ac converters. This change requires the massive and widespread use of information and communication technology (ICT) to ensure that a potentially volatile smart grid remains stable.

In addition to engineering graduates who have a broader skill base and a drive to succeed in a leadership role, utilities in Europe also require specialist graduates who understand computer-based system optimization, the design attributes of resilient energy systems, and the application of digital technology to power system control, to name the most important expertise requirements. The techniques and methodologies for transforming a traditional, fossil fuel-based power grid into an active low-carbon grid are of utmost importance as well. Graduates must fully recognize the role of consumers and prosumers in keeping the lights on at an affordable economic and environmental cost to society.

Traditional job security in power-related utilities and manufacturing is declining. Long gone are the days when graduate engineers left universities to join formal two- or three-year graduate training programs and then climbed the corporate ladder from second to first to senior engineer and then perhaps after ten to 20 years moved to a technical, commercial, or corporate middle-management position. Electrical engineering graduates often join smaller companies with shorter and less formalized training programs and immediately move into a technical support role, followed by rapid progression into a leadership position within a small technical team. This change from a traditional hierarchical pyramid organization into a flat "rapid-initial progression" structure tends to discourage corporate loyalty. Engineers regularly switch companies or transfer from the power utility sector to consulting companies that advise, design, and help build our future power networks.

In the era of smart grids, energy sustainability, and increasing environmental constraints, many opportunities are emerging for future engineers and, in particular, for electrical engineers. In "Energy Roadmap 2050" issued by the European Commission, one of the conclusions from the analysis of different decarbonization scenarios is that electricity is expected to play a growing role in all situations, significantly increasing its share of the final energy demand (36–39%) with respect to its current value (25%) by 2050. To contribute directly to scientific projects and research and demonstration programs, the European Union has defined a Strategic Energy Technology Plan (SET-Plan). One of the actions in place, called Universities in the SET-Plan (UNI-SET), is coordinated by the European University Association and refers to research, innovation, and education in the energy field. In its recent report, examples are provided by focusing on three SET-Plan areas: 1) energy efficiency, 2) smart grids and energy systems, and 3) renewables integration. In all of these areas, there is a close interaction with the competencies of electric power engineers.

Electrical engineering curricula generally contain significant interdisciplinary content, ensuring that electrical engineers are the most versatile of all engineers and their skills enable effective interaction with the wide range of personnel operating in the industrial and ICT sectors. For these reasons, the public often raises questions about the difference between electrical and electronics engineers or between electrical and energy engineers. Indeed, as previously mentioned, the electric power engineer is educated in a number of core topics that are not taught in other engineering courses. As a matter of fact, the basics of power engineering are absent in practically all of the other curricula associated with industrial engineering and information science.

Electric Power Engineering Education in the United Kingdom

When considering their careers, students registered for three-year bachelor of engineering (B.Eng.) or four-year master of engineering (M.Eng.) degree programs in electrical and electronic engineering (EEE) in the United Kingdom often inquire about the opportunities available in electric power engineering and require answers to some or all of the following questions.

- ✔ Can career opportunities in the electrical power sector compete with those in the microelectronics, communications, software design, data analysis, and financial service sectors?
- ✔ Is it possible to have a rewarding and challenging career in a power utility?
- ✔ Will the United Kingdom continue to be a leading manufacturer of power equipment and systems, and are jobs in the manufacturing sector secure?
- ✔ U.K. network utilities are financially encouraged to deliver low-carbon smart grid trials, but when will the

technology and ideas associated with these trials be rolled out as business as usual?

- ✔ If I want to become an electric power engineer, should I join a consulting company, a construction company, a generation company, a manufacturer, or a utility?
- ✔ Regarding careers in network utilities, what are the advantages and disadvantages of joining a distribution network company, the Great Britain transmission system operator, or a transmission network owner?

The reasons for their lack of knowledge in these areas and their perception of a traditional industry struggling to cope with the impact of new technology are related to the partial failure of the energy industry, the media, professional bodies, and the education sector to adequately inform society and especially schools about the exciting opportunities available for professional power engineers. How often does a mainstream TV channel describe the importance of low-carbon electricity to society, the complexity of our networks, the challenges and opportunities in switching from fossil fuels to renewables, and the importance of electrical engineers in keeping our lights on?

To ensure that an adequate number of appropriately trained electrical engineering graduates are available to join the power and energy sector, the following issues are becoming more important.

- ✔ British universities must offer attractive academic careers for high-quality Ph.D. graduates in electrical power-related disciplines.
- ✔ The global success of a university depends on its ability to attract and keep the best researchers from Europe and the wider world.
- ✔ New researchers and academics must receive greater support from industry, utilities, government research councils, energy regulators, and universities to help them develop their research, teaching, and innovation capabilities within the resilient low-carbon energy sector. This requires public and private organizations to take a long-term view on the importance of electrical power networks, low-carbon technologies, and renewable energy sources and commit greater funding for innovative and speculative research and outreach activities.
- ✔ Undergraduate and postgraduate programs need updating to ensure students are educated and trained in the skills required for an energy future dominated by renewables, storage, and demand-side management.
- ✔ Many students do not have adequate access to practical laboratories and often rely on offline computer simulators that fail to deliver an understanding of power engineering. Greater investment is required in state-of-the-art laboratories (e.g., Figure 1) that allow students to use real-time digital simulators and replay test sets in experimental test benches to evaluate commercial power system control equipment, power electronic systems, and other low-carbon technologies.

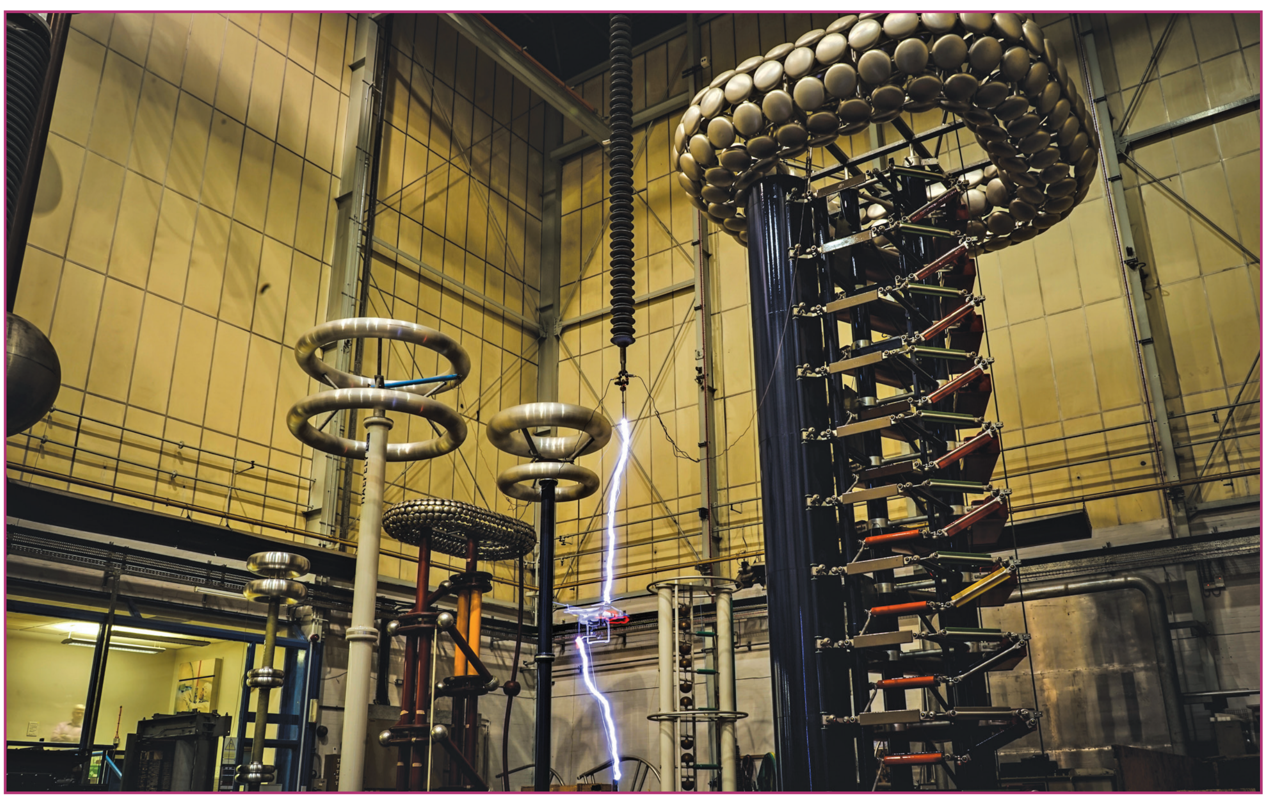

figure 1. A student located in the control room is flying a drone too close to the HV Impulse Generator. (Photo courtesy of the University of Manchester.)

> Electrical engineering curricula generally contain significant interdisciplinary content, ensuring that electrical engineers are the most versatile of all engineers.

Students need access to hands-on experimental laboratories and project activities to help them understand how a smart grid will be designed and operated in the future.

- ✔ Significant investment is required in many electrical power laboratories to ensure that the experimental activities are relevant and can be linked to simulation studies. These laboratories were often established using U.K. government funding, but modernization generally involves investment by individual universities and sponsoring companies. Companies operating in the power sector and the professional bodies that represent power engineers need to do more to explain the importance of power networks and the energy sector to young people and the teachers, guardians, and advisors who influence their future.
- ✔ Many teachers fail to recognize the importance of electrical power and low-carbon energy systems and why careers in this sector are personally, socially, and financially rewarding. Universities need to engage with teachers in secondary schools (where students are ages 11–18) and ensure that they are aware of the career opportunities available for EEE graduates. A typical graduate will normally have joined a leading university EEE course with three very good advanced-level qualifications in mathematics, physics, electronics, chemistry, computing, or additional mathematics.
- ✔ Students perceive careers in IT and software as providing major future employment opportunities but do not realize that learning skills in these areas is directly applicable to careers in smart grids and the low-carbon energy sector.
- ✔ The media need to recognize the challenges and opportunities in delivering a smart, low-carbon energy system and explain why smart grids, renewable energy, and carbon-reduction incentives are required to achieve long-term sustainability.
- ✔ The transformation of a fossil-fueled energy economy to one based on renewables and low-carbon sources is probably the greatest challenge modern society has faced. Success will depend on consistent and logical government policies and wider social support. One priority is to ensure that the very best students study engineering and receive a high-quality university education that prepares them for a successful and rewarding career in the power and energy sector.

Students often do not recognize the importance of power utilities and the challenges in operating the largest and most complex of all human-made systems, especially as we switch from fossil fuels to renewable energy. This transformation requires greater use of advanced control technology, power electronics, and storage.

Many universities in the United Kingdom offer a three-year B.Eng. or four-year M.Eng. undergraduate EEE degree program. The entrance requirements for a B.Eng. degree program in a leading EEE school are often a grade of A in advanced-level General Certificate of Education in mathematics and physics and an A or B in another relevant advanced-level course. The entrance grades for an M.Eng. degree are normally slightly higher than for the B.Eng. degree.

The first year of a typical B.Eng. undergraduate EEE degree involves a 50:50 split between academic contact time (lectures, tutorials, problem-solving classes, and laboratories) and independent study. In subsequent years, the expectations for independent study increase, and, by the third year, the expected split has changed to 33:67. This is designed to encourage independent learning and prepare the student for postgraduate employment or further study at the master's degree or doctoral level. A typical first year involves compulsory courses in mathematics, circuit analysis, digital systems, microcontrollers, energy transport and conversion, electromagnetism, electronic circuits, programming, electronic materials, and measurements. Most courses continue to offer a broad EEE curriculum in the second year, with power-related specialization in year three. Most universities also offer an individual project in the third year; this is generally on a topic of interest to the student and the project supervisor.

Many students graduating with a three-year EEE B.Eng. degree will enhance their knowledge in electrical power by studying a one-year intensive master's degree program. A typical program in electric power systems engineering covers the operation and plant aspects of a conventional utility power system and the changes necessary to deliver a smart grid using demand management, storage, and intermittent renewable sources of energy. The main emphasis is keeping things in balance: not just the balance between generation and load or the production and consumption of reactive power but also the balance between the cost of energy and its environmental impact and between the reliability of the supply and the investment needed to develop the system. The program teaches the students to quantify these tradeoffs and improve the balances using technological advances and sophisticated computational techniques.

> The basics of power engineering are absent in practically all of the other curricula associated with industrial engineering and information science.

The first semester of one particular program consists of four compulsory, three-week intensively taught units, each including laboratories and course work. It starts with an introductory unit in EESs designed to ensure that all students have a reasonable understanding of energy systems. This is followed by units on the analysis of electrical power and energy conversion systems; power system plant, asset management, and condition monitoring; and power system operation and economics.

During the second semester, the program explores, in more depth, the operation and plant aspects of power systems. For example, students learn how to integrate renewable generation into a power system and how to assess and solve power-quality problems. Units in this semester are power system dynamics and quality of supply, power system protection, smart grids and sustainable electrical systems, and a generic unit on techniques for research and industry applications.

Upon completion of classes in June, each student begins a three-month dissertation project designed to enhance research and engineering skills and generally explore in depth a topic discussed during the course.

The Engineering and Physical Sciences Research Council Centre for Doctoral Training in Power Networks

In 2013, the U.K. Engineering and Physical Sciences Research Council (EPSRC) invited U.K. universities to apply for funding to support Centres for Doctoral Training (CDTs) in a wide range of topics related to science and engineering. Funds were awarded and a multidisciplinary CDT in Power Networks established in 2014 for 11 Ph.D. students per year, for an initial recruitment period of five years, with a possible extension to ten years. Each of the existing Ph.D. students in the center is registered for a four-year enhanced Ph.D. degree program that starts with a nine-month structured training program, referred to as a postgraduate diploma, which is followed by a Ph.D. degree-level research project lasting 39 months.

The center is funded by the British government, and consequently most of the students joining the scheme must be British citizens or EU nationals with residency in the United Kingdom. However, some flexibility is possible for a small number of students. For example, one international student and one EU student who fails the residency requirement are recruited each year. During their studies, each student receives a grant that covers his or her tuition fees and an enhanced living stipend. In conjunction with their project supervisors, students can apply for funds to support their consumable costs, travel budgets, and conference/journal fees.

The strategic vision of the EPSRC CDT in Power Networks is to

- ✔ provide a stimulating and interdisciplinary doctoral training program in power networks that emphasizes reliability, efficiency, and use of low-carbon energy sources and maximizes the societal and economic opportunities created by prosumers and flexible demand
- ✔ produce highly employable, skilled, and talented researchers equipped to solve the multifaceted challenges facing the energy sector and the wider U.K. economy
- ✔ develop researchers with the ability and drive to become the next generation of internationally recognized power network academics
- ✔ deliver a challenging and broad-ranging program that fully prepares students for individual Ph.D. research projects building on expertise in interdisciplinary power network research
- ✔ ensure the standards for student supervision, management, and mentoring are all high quality
- ✔ work with partners to ensure that students learn the essential transferable and generic skills required for successful professional careers in the diverse power network sector
- ✔ ensure that all Ph.D. graduates have the ability to deliver cost-effective and high-quality research solutions to the power network issues raised by the need for a low-carbon energy future
- ✔ widely disseminate research results, ideas, and concepts to professional power network communities and learned societies and ensure all Ph.D. students engage in outreach activities and are science/technology/engineering/mathematics ambassadors
- ✔ create a cross-disciplinary center that delivers world-leading research in the power network area, involving academics and Ph.D. students from the humanities, engineering, and physical sciences disciplines as well as industrialists and policy makers from the wider U.K. energy community.

Electrical Engineering Education in Italy

In 1999, the Italian educational system reformed by adopting the Bologna system, also called 3 + 2. University curricula were partitioned into three levels, the first (bachelor's degree) level being three years in length, the second (master's degree)

> The electric power engineering sector is undergoing significant transformation in preparing an exciting professional future for our students.

level two years, and the third (doctorate) level three years. This structure was introduced to enable an earlier conclusion of a university path (with respect to the former five-year curricula) for those students desiring to enter the workforce without completing the entire path. The engineering curricula were restructured according to the Bologna system rules. The target of the reform was approved by industry, and the Italian Professional Association of Engineers created the new category of junior registered professional engineer to align with the new structure. During the curricula planning and annual update, universities are required to consult with the relevant employers to solicit their opinions on the curricular structure and contents.

At the first and second levels, the university curricula are grouped into classes. Unlike in the United States, where the term *power engineer* is typically used, in Italy there is no strict definition of a power engineering class. The closest class is electrical engineering, the name of which was officially introduced in Italian legislation in 1989 to replace the former designation of *electrotechnics engineering*, which had been used since 1938. At the first level, electrical engineering is part of the industrial engineering class. At the second level, there is a dedicated electrical engineering class. At the third level, there are specific courses covering dedicated topics included in the doctoral course offerings of individual universities.

The European Credit Transfer and Accumulation System (ECTS) establishes a way to represent the volume of learning based on defined learning outcomes and their associated workload. Basically, one ECTS credit corresponds to 25–30 h of activity in a course, including lectures, classwork, laboratory activity, and personal study (the figures vary for different countries). The standard number of ECTS credits in one academic year is 60.

Since 1990, each university staff member has been assigned to a unique national sector. These sectors are also used to define the characteristic areas of each class of university courses. For the electrical engineering class, the characteristic areas include four sectors, i.e., electrotechnics; converters, electrical machines, and drives; electrical energy systems (EESs); and electric and electronic measurement. The sector closest in content to power engineering is certainly EESs. The main topics of this sector refer to technologies and systems for the production, transmission, distribution, and utilization of electricity. More generally, the applications considered concern all systems with interconnected components that use a significant amount of electricity. Many themes are addressed by the sector, including automation, diagnostics and reliability, operation and planning, energy efficiency, materials for power system applications and high-voltage engineering, electromagnetic compatibility and quality of supply, safety and security, power system economics and electricity markets, electrified transportation, electrical plants for fixed and mobile installations, smart grids, and the power domain expertise for ICT and data analytics.

The Italian university staff positions are full professor, associate professor, and researcher. In the last ten years, the total number of university staff in the EES sector has remained almost unchanged (118 in 2007 and 119 in 2017). However, the composition has changed. The number of full professors has decreased by 29%, the number of associate professors has increased by 29%, and the number of researchers has remained stable, even though in 2007 the researcher position was full time, while now 47% of the researchers are part time (a few of them are enrolled on tenure tracks, with the possibility of becoming associate professors after three years). The portion of women among the staff is 13%. Furthermore, the number of research assistants with grant funding and doctoral students in the EES sector increased from 85 in 2007 to 100 in 2017.

Concerning academic duties, full and associate professors enrolled with the current rules have a target of 120 h per year to be spent in course activities with the students (excluding examinations). For researchers, the target is 60 h/year. Since the number of students in the electrical engineering courses is generally not very high (fewer than 60 in most cases), examinations are often conducted orally, with a significant number of hours dedicated to them by the examination commission (typically composed of two persons). The examination periods are scheduled between semesters when the students do not attend any courses; generally, students have the choice of at least four sessions in one year, during which they can decide to take the examination for the same course. If the student does not pass the examination, he or she has to include its ECTS credits in the following year's list of courses.

Italy's last reform of university studies introduced a process that includes the self-evaluation, periodic evaluation, and accreditation of curricula. This process requires the preparation of documents that indicate the activity carried out in the study courses, according to a format provided by the National Agency for the Evaluation of the University System and Research. This is based on the following elements.

- ✔ *The description of the study courses*: This is updated every year and contains information on the objectives and plan, the organization of the teaching activities, the syllabus of each course and its delivery modes, the rules for the exams, the human resources and infrastructure available, a description of the students' results in relation to the course objectives, and the organization and responsibilities concerning quality assurance for the course. The description also contains indications on the professional profiles to be formed and on interactions with the representatives of the relevant employers.
- ✔ *The delivery of questionnaires to the students*: These instruments gather information on teaching activity and logistics and services offered. The results of the questionnaires are then handled by the Joint Committee on Teaching, active in each university and composed of an equal number of professors and students. This committee is responsible for delivering an annual report on teaching activities.
- ✔ *The annual review of the study courses*: This is a self-evaluation step carried out by suitable committees active in the university.
- ✔ *The periodic review of the study courses*: This step was recently organized with a three-year schedule, to be carried out by an external committee of evaluators. The review is aimed at providing accreditation of the curricula for the successive period.

Some curricula also receive accreditation from international bodies active in the specific domain.

Electrical Engineering Courses in Italy

The bachelor's and master's degree curricula in electrical engineering with EES-related contents are active in 17 Italian universities, with 121 courses delivered, for a total of 976 ECTS credits. Among them, at the bachelor's degree level (active in 17 universities), there are 31 mandatory courses (257 ECTS credits) and six elective courses (34 ECTS credits). At the master's degree level (active in 16 universities, Figure 2), there are 64 mandatory courses (550 ECTS credits) and 20 elective courses (135 ECTS credits). Table 1 reports the distribution of the total number of courses taught by EES staff among the various topics. The number of ECTS credits for these courses ranges from six to 12. At the bachelor's degree level, the main contents of the power engineering area are delivered in a general course on electrical systems. At the master's degree level, the contents referring to power engineering are spread among more courses, starting from the power system basics and continuing with advanced content, particularly on

figure 2. The sites in Italy with the master's degree courses after curriculum restructuring.

table 1. The topics of the courses taught by EES staff in the bachelor's and master's degree curricula with electrical engineering content in Italy.

Topic	Number of Courses: Bachelor's Degree Level	Number of Courses: Master's Degree Level
Electrical systems (in some cases including power system basics)	15	4
Power system basics	0	14
Power system control	1	10
Generation systems	1	7
Renewable energy	3	2
Distribution systems	6	4
Smart grids	0	4
Power system economics/energy systems	2	5
Electric technologies/high-voltage engineering	1	5
Industrial electrical systems/design/safety	4	9
Automation/intelligent systems/lighting	2	9
Reliability/quality of supply	2	4
Electrical systems for transportation	0	7
Total	**37**	**84**

generation systems, power system control, smart grids, and electrical systems for transportation.

Students Enrolled and Graduated

After the introduction of the Bologna system, the Italian university courses were restructured once, keeping the 3 + 2 scheme. The new structure was applied starting with the 2009–2010 academic year. For the master's courses in electrical engineering, the transition from the previous courses (labeled LS/31) to the new ones (labeled LM/28) brought an increase in the total number of students and graduates and also a growth in the number of females, but that is still a very small number. Figure 3—prepared by using data provided by the Italian Ministry for Education, Universities, and Research (MIUR)—shows the recent evolution of the number of graduates in Italy. The distinction between the previous and new courses indicates the effect of the application of the reform.

However, the increase in the number of graduates has to be considered by taking into account that the overall number of students enrolled in technical universities has increased over the years in a nonuniform way for the various sectors. For example, from academic years 2011–2012 to 2016–2017, the number of students enrolled in engineering courses grew by about 27%. During the same period, the number of students in the electrical engineering courses increased by 39%, while, in the electronics engineering and telecommunications engineering courses, this number remained almost constant. In academic year 2016–2017, the total number of students enrolled in the electrical engineering master's degree courses was about 660, with a similar number for telecommunications engineering, while electronics engineering had about 1,000 enrolled master's degree students. An increase of about 40% also occurred in the classes of energy and nuclear engineering, mechanical engineering, materials engineering, and aerospace engineering. In these classes, however, the presence of electrical engineering content is rather limited.

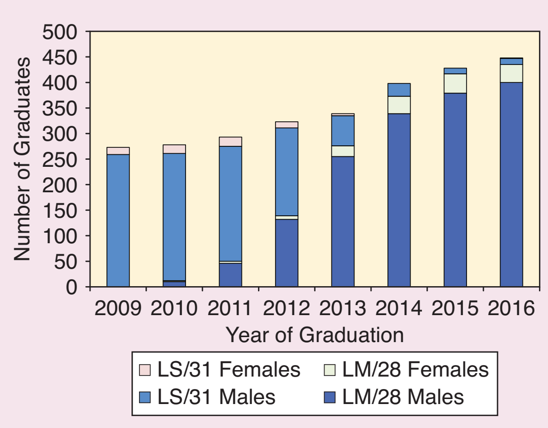

figure 3. The number of graduates in Italy in the electrical engineering master's degree courses before restructuring (LS/31) and after restructuring (LM/28).

A different development took place for the bachelor's courses. The 3 + 2 reform created a single industrial engineering class, leaving the possibility for the universities to start different courses inside that class. Some restrictions imposed on the number of staff needed to start each course led to the creation of courses in electrical engineering or electrical energy engineering (the literal translation from Italian) in only a few universities (typically the largest ones). In other universities, the topics characterizing electrical engineering were incorporated into courses of energy engineering or industrial engineering, losing the *electrical* brand. In the 2016–2017 academic year, about 25,000 students were enrolled in 114 courses at the bachelor's level.

Students in Italy pay university fees for their enrollment. The maximum amount of these fees is defined by each university and can change with the type of course. Fee reductions generally depend on the income of the student's family, and the payment is distributed among two or three tranches throughout the year. For the engineering courses, for full-time students, the annual fees range from about € 500 to over € 3,000, plus regional taxes. The annual fees cover a number of ECTS credits that the student may upload into his or her annual course plan, which varies with the university (e.g., from 74 to 80 ECTS credits). An additional option is to register as a part-time student, with reduced fees corresponding to a lower number of ECTS credits that may be uploaded. Furthermore, partial reimbursement of the fees may be provided on the basis of the number of exams passed and the related scores, depending on local rules and on the amount of funds available for this purpose.

Threats to the Electrical Engineer Brand

A new wave of reform is taking place in Italian universities. The main idea is to create larger structures (departments) and broader curricula with respect to the present ones, with the aim of organizational simplification and cost reduction. In some cases, this is leading to the decline of the electrical engineer's status. For example, the word *electrical* is being lost in the names of university departments and in the main names of courses and curricula. At the bachelor's degree level, the term *electrical* (or *electrotechnics*) appears in nine main course titles and in another five curriculum subtitles, while in three other cases, the course title is *Industrial Engineering*. At the master's level, the term *electrical* (or *electrotechnics*) still appears in the title of all 16 universities' courses, in three cases in the form *electrical energy*, and this has been successful in attracting students in the corresponding institutions.

Another example is given by the doctoral courses active in the 16 universities that offer master's courses with electrical engineering content. The term *electrical* appears in the main title of nine courses and in the subtitle indicating a specific curriculum for two more courses. In the other five

> The uniqueness and peculiarities of the knowledge and skills needed to become an electric power engineer with specific competencies have to be preserved.

universities, the main titles of the doctoral courses are varied and contain terms referring to energy, information technologies, and industrial engineering.

Maintaining an understandable and meaningful terminology is a key challenge for the electrical engineering community. In the near term, the loss of the electrical engineer brand could conceivably interfere with the immediate understandability of graduates' skills and certainly would not contribute to clarifying electrical engineers' specific competencies.

Employment Opportunities for Electrical Engineers

Some comparisons are addressed in this section that are based on statistics from the interuniversity consortium Alma Laurea website. This consortium is funded by a large number of universities (representing over 90% of graduates) and by contributions from MIUR and the companies and bodies that use the services offered. The statistical data come from a massive survey conducted every year in Italy of university students immediately before they complete their bachelor's or master's degree and again one, three, and five years after they obtained their degree.

The comparisons are carried out by considering the national average values for the entire set of courses (denoted by "All"), the average values for the courses in the engineering classes (denoted by "ENG"), and the values for the bachelor's degree courses in industrial engineering (the L-9 class) and for the master's degree courses in electrical engineering (denoted by "EE"). One of the questions on the survey aims to determine the students' degree of satisfaction just before completing their course of study. In particular, this satisfaction measure suggests the percentage of the students who would take the same course again.

At the bachelor's degree level, the number of individuals who look for employment after completing their degree in electrical engineering is relatively low. In recent years, a reduction in the number of students completing their bachelor's degree has been caused by the closing of many distance-learning courses, which, for many years, allowed those already employed and willing to continue their education to obtain their degree. From the results of the survey given to 144,646 students who obtained their bachelor's degree in 2016 (92.7% of the total), the students who intended to continue at the master's degree level constituted 57.8% for All, 83.5% for ENG, and 89.4% for L-9. The positive outcome for L-9 is also reinforced by the satisfaction results, which reach 79.2% for All, 84.0% for ENG, and 86.1% for L-9.

At the master's level, electrical engineering courses perform quite well in the national context. Table 2 presents some statistics regarding 2015. The data are taken from a massive survey of 62,710 graduates of the master's degree courses one year after graduation (82.1% of the total number of master's degree graduates in Italy), together with 57,862 individuals three years after graduation (74.8% of the total) and 46,461 five years after graduation (72.1% of the total). The comparisons are carried out by considering the national average values for the entire set of master's degree courses (denoted by "All"), the average values for the master's degree courses in the engineering classes (denoted by "ENG"), and the values for the master's degree courses in electrical engineering (denoted by "EE"). The surveyed items were

- ✔ employment rate, determined by the percentage of graduates who were employed at the time of the survey
- ✔ the effectiveness of the master's degree, assessed by indicating whether the specific master's degree proved useful for the activity carried out in the job(s) found after graduation
- ✔ salary increase, with respect to the average salary of the All category after one year from graduation.

For all of these items, the figures for EE are always higher than the average values for ENG, which, in turn, are much higher than the national average for the All category of the master's degree courses. In addition, the average values after one year from the completion of the master's courses in ENG

table 2. Some comparisons referring to graduates in master's degree courses in Italy.

	After One Year			After Three Years			After Five Years		
	All	ENG	EE	All	ENG	EE	All	ENG	EE
Employment rate	69.2%	85.7%	88.7%	81.5%	93.6%	95.3%	84.0%	94.3%	97.3%
Master's degree effectiveness	46.6%	58.9%	63.6%	50.7%	59.0%	66.1%	53.7%	59.1%	67.8%
Salary increase with respect to base	0 (base)	23.8%	29.5%	11.1%	36.4%	42.3%	22.6%	52.0%	53.3%

> The IEEE PES and sister societies should intensify the promotion of the professional role of the electric power engineer through the media and social networks.

(and, even more, the values for EE) are higher than the ones reached five years after graduation in the national average. In particular, the employment rate for electrical engineers is already significant one year after graduation and almost doubles after five years.

The effectiveness of the master's degree grows over the years, as the graduates have to face an increasing number of challenges, and this raises their awareness of the skills they learned. The salary increase is a tangible outcome to motivate the graduates to continue their activity in the EE domain. With respect to salaries, the graduates employed abroad have a significantly higher average salary compared to the average salary in Italy (e.g., 50% higher or even more). This also reflects the higher effectiveness of the master's degree felt by the graduates employed abroad (about 8% more than those employed in Italy).

An additional survey was carried out on 91.4% of the students (e.g., Figure 4) completing master's degree courses in 2016, contacted before graduation to determine their degree of satisfaction. By using the same categories discussed previously, the results show 83.9% satisfaction for All, 88.5% for ENG, and 90.9% for EE. This is another strong indication of the effectiveness of the master's degree courses in EE in Italy.

At the Ph.D. level, the regulatory framework in Italy rigidly fixes a unique national starting date per year for each doctoral cycle. This can make it difficult to retain the best students, who may graduate at different times during the year. This structure is poorly competitive with the higher flexibility of the starting date for a doctorate in other countries. This results in a significant number of graduates who continue their studies in a doctoral course abroad. In addition, the grant offered to doctoral students in Italy is rather low with respect to many other countries, and the practical consideration of Ph.D. degree holders in the Italian job market in terms of the position and salary offered is still lacking.

Recent initiatives, such as the industrial doctorate that has been offered since 2013 and defined in close collaboration with industry, are gaining relevance as they try to mitigate the gap between the skills acquired during the doctoral period and the opportunities available after concluding the degree. In this way, the number of Ph.D. graduates could increase, and their stature should rise in the areas of industry and utilities, moving beyond the concept that Ph.D. degree formation leads only to a career in research and teaching at a university.

Initiatives to Promote Electrical Engineering Courses

An effective way to revamp students' interest in electrical engineering and attract highly qualified engineering students to the electrical area is incentives and awards. The number of initiatives active in Italy has recently increased. For example, the Italian Electrotechnical Committee—the Italian standardization body—traditionally presents three awards for the best master's theses prepared on topics linked to the standards for electrotechnics, electronics, and telecommunications. In 2018, the Italian Association of Electrical, Electronic, and Telecommunications Engineers, a nonprofit organization that has

figure 4. The electrical engineering master's degree graduation ceremony at the School of Engineering and Architecture, University of Bologna, Italy, 21 December 2017. (Photo used with permission from C.A. Nucci.)

promoted activities in those related fields in Italy since 1897, offered free first-year registration to new members under 24 years old. In addition, various associations and some private industries have introduced master's thesis awards, free seminars, and courses on topics related to electrical engineering, among others. The voice of industry is particularly important for reaching the public in a period during which electrical engineers are critical for the development of current and emergent solutions in the power and energy sector.

Similar initiatives developed by the IEEE Power & Energy Society (PES) are in place in Italy. The Scholarship Plus Initiative, launched by the IEEE PES in academic year 2011–2012, was implemented in Italy for the first time in 2017. On 26 September 2017, during the Seventh IEEE International Conference on Innovative Smart Grid Technologies, held in Torino, Italy, the IEEE PES Italy Chapter Award Committee delivered four 2017 IEEE PES Italy Scholarship Plus awards to undergraduate students enrolled in electrical engineering courses. Additional initiatives are expected to promote electrical engineering courses, and incentives to increase the number of female power engineers will be clearly welcome.


SHUTTERSTOCK

figure 5. Renewable energy conversion and grid integration will be key challenges for power engineers.

Summary

The electric power engineering sector is undergoing significant transformation in preparing an exciting professional future for our students. Universities are actively participating in these transformations, taking responsibility for training a new generation of experts capable of applying their competencies by working closely with experts in other domains. Updated or new curricula will require a trade-off between specialized courses for the creation of a highly skilled workforce of specialists in the electric power engineering domain and more general courses for students who require a broad range of interdisciplinary content. The uniqueness and peculiarities of the knowledge and skills needed to become an electric power engineer with specific competencies have to be preserved. The electrical engineer or power engineer brand, historically well identified by employers, has to be defended against the risk of being lost by the submerging of power engineering content in wider curricula.

As a matter of fact, while, on the one hand, we are observing an unprecedented electrification of our cities, communities, and our society in general—for example, the integration of renewable energy (e.g., Figure 5) and electric vehicles—it is also clear that the number of students who join electrical engineering programs is not increasing enough. Consequently, meetings and international conferences organized by the IEEE PES and sister Societies should intensify the promotion of the professional role of the electric power engineer through the media and social networks.

For Further Reading

European Commission, "Energy roadmap 2050," European Commission, Brussels, Belgium, Tech. Rep. COM (2011) 885 final, 2011.

European University Association. (2017, Dec.). Energy transition and the future of energy research, innovation and education: An action agenda for European universities. [Online]. Available: http://www.eua.eu/Libraries/publications-homepage-list/energy-transition-25-01-2018

B. H. Chowdhury, "Power education at the crossroads," *IEEE Spectr.*, vol. 37, no. 10, pp. 64–69, 2000.

European Credit Transfer and Accumulation System. (2015). ECTS users' guide 2015. [Online]. Available: http://ec.europa.eu/education/ects/users-guide/index_en.htm

Italian Ministry for Education, Universities, and Research. Higher education in Italy. [Online]. Available: http://www.miur.it/guida/guide.htm (accessed 2018, June).

Alma Laurea. Employment condition of the graduates (in Italian). [Online]. Available: http://www.almalaurea.it/universita/occupazione/occupazione14

G. Betis, C. Cassandras, and C.A. Nucci, Eds., *Proc. IEEE* (special issue on smart cities), vol. 106, no. 4, Apr. 2018.

Biographies

Gianfranco Chicco is with Politecnico di Torino, Italy.

Peter Crossley is with the University of Manchester, United Kingdom.

Carlo Alberto Nucci is with the Alma Mater Studiorum–Università di Bologna, Italy.

p&e