

Master's degree in Nuclear Engineering UPC-ENDESA. A consolidated international program.

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Summary – The Master's degree in Nuclear Engineering (MNE) UPC-ENDESA offers a unique and practical oriented training, with the aim to prepare competent engineers so that they can assume managerial positions within the Nuclear Industry. The program combines science, technology and management in the nuclear energy field, including the elements of the safety culture. MNE is embedded in EMINE, the European Master in Nuclear Energy (KIC InnoEnergy) and is completely taught in English. Its 90 credits (each credit implies 25 hours of student's work) are divided into one year of subjects (60 credits), and one semester of internship plus final project (30 credits). MNE has a strong industrial implication: lecturers from companies, research institutes and the Spanish Regulatory Authority (cover about one half of the lectures; companies accept students in internships and organize technical visits. The participation of professionals external to the University in the definition and revision of the Program is one of MNE's assets. A large portion of the contents of the MNE are organized in the form of Problem and Project Based Learning: real industrial problems are brought into the classroom to be solved by students, most of the time assisted by experts from the nuclear industry. MNE is in continuous evolution, seeking for a continuous improvement of the contents and learning methods. Starting the sixth edition, the master is firmly consolidated and the alumni value it positively.

1. INTRODUCTION.

The Master's degree in Nuclear Engineering (MNE) UPC-ENDESA [1] aims to prepare engineers with a high level of competencies so that they can assume managerial positions within the Nuclear Industry, which demands professionals able to work rigorously, accordingly to the Safety Culture, imbued of a high sense of responsibility, and at the same time able to work in an international context, within transcultural teams and in a continuously changing environment.

The Programme was born, with a clear industrial vocation, in 2010 when Endesa, the largest nuclear plant operator in Spain, approached UPC with the aim to start defining a future Master in Nuclear Engineering in Barcelona. The contents and scope of the master were defined with the contribution of professionals from industry, the CSN and research and academic institutions. Early in 2011 the Program was submitted to the National Agency for Quality Assessment and Accreditation of Spain (ANECA) for verification. In March same year a Memorandum of Understanding UPC-Endesa was signed, by which Endesa committed to sponsor the Master. In October 2011, the first edition of the Master started. In 2015 the Program was accredited by ANECA.

The Programme is characterized by a strong industrial implication that makes it possible to offer a unique and practical oriented training. It combines science, technology and management in the nuclear energy field, including the elements of the safety culture.

MNE is embedded in EMINE, the European Master in Nuclear Energy (KIC InnoEnergy) [2].

After five editions, the Programme is firmly consolidated and the alumni value it positively. This September, the sixth edition has been launched.

2. DESCRIPTION OF THE PROGRAMME.

The MNE program has been designed to help students:

- Understand the theoretical and practical fundamentals of nuclear engineering.
- Acquire a clear vision of the nuclear fuel cycle, from uranium mining to the management of spent nuclear fuel.
- Comprehend the lifecycle of the different installations, from the erection to the decommissioning of a nuclear facility.
- Gain a deep understanding of regulation and apprehend the principles of nuclear safety.
- Develop a strategic view of the nuclear industry and the ability to formulate problems and to make decisions.

The Master's 90 credits are divided into one year of courses (60 credits) and one semester of internship plus master thesis (30 credits). The Programme is fully adapted to the European Higher Education Area (EHEA) standards and each credit implies 25 hours of students' work, be it in the classroom, in the laboratory, in a field visit, before a computer, or reading their notes when preparing for an exam, to mention some of the activities. Table 1 gives an overview of the distribution of the credits.

In order to help students gain the competences needed to manage the kind of projects developed in the industry (material supply logistics, plant safety and technical management), an important part of the contents of the MNE are organised in the form of Problem and Project Based Learning. The courses and their respective allocated credits are listed in Table 2. Figure 1 illustrates the temporal organization of the contents with an indication of the transversal character of the two Course Projects.

MNE is completely taught in English, to attract international students and to train Spanish students to compete in an internationalised labour market.

3. LEARNING METHODOLOGY

To achieve meaningful learning, learners must face realistic situations, similar to those encountered in the workplace; they have to apply their knowledge to address problems whose solution requires making decisions. For this reason, active learning methodologies and team work are thoroughly used in the master. Assessment instruments and activities are integrated into the learning activities.

As aforementioned, an important part of the contents of the Master are dealt with by means of a Problem or Project Based Learning (PBL) framework, which has shown to be quite adequate in the engineering education and training.

Table 1. Structure of the MNE programme.

Type of Subject	Credits
Required courses	46.5
Elective courses	13.5
Internship	15
Master's Diploma Thesis	15
TOTAL	90

Table 2. Credits allocated for the different courses.

Courses	Credits
First Semester	
Fundamentals of Nuclear Engineering and Radiological Protection	8
Reactor Physics and Thermal-Hydraulics	7.5
Systems, Components and Materials	6
Fuel Cycle and Environmental Impact	5.5
Course Project 1	3
Second Semester	
Regulations and Safety	5
Management of Nuclear Power Plants	8.5
Elective subjects	3 x 4.5
Course Project 2	3

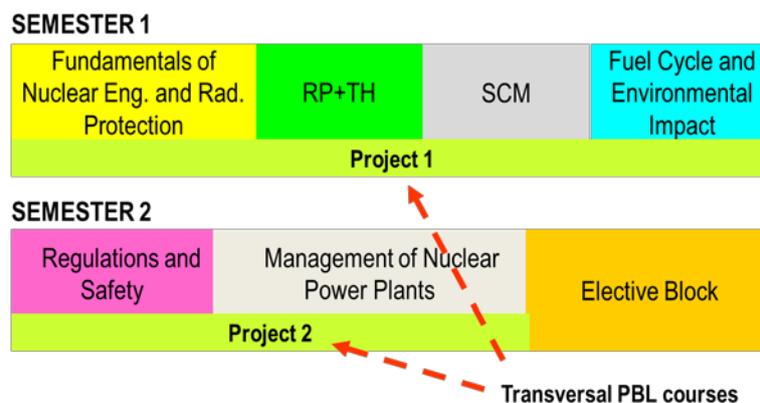


Figure 1: Distribution of the curriculum in semesters.

For instance, in the recent editions, the transversal project developed during the second semester has been a 'Feasibility study of plant power up-rating'. Beyond the small courses organized as projects (*Project 1* and *Project 2*), PBL techniques have been used, for instance, within the course *Management of Nuclear Power Plants* (MNPP), when students have been faced with the "Design of a portable system to support the operation in Station Blackout scenarios" (more details of these activities can be found in Reventós et al. [3]). These projects, scheduled in the second semester, are mentored by specialists from industry together with academic staff.

The master aims to ease students' transition from University to Industry. The industrial internship in the third semester is part of the strategy. Another part is the fact that towards one half of the classes are delivered by lecturers external to UPC (half of them from the Industry); this

participation is more relevant in subjects of the second semester. Students' visits to industrial facilities complete the strategy.

4. INDUSTRIAL VOCATION

The MNE was born from the alignment of objectives of Academy and Industry; from the of Endesa's and UPC's commitment to maintain and nurture the know-how in nuclear engineering education in a social and political context that makes this task difficult.

Because of its penetration in the Spanish Energy System, Endesa has eased the path for MNE in order to obtain the collaboration of the Spanish Nuclear Industry. Industrial collaboration includes one or more of the following activities: lecturing, organization of guided visits, hosting of students for internships, guidance in the definition of the contents of the master.

The implication of a large part of the Spanish Nuclear Industry has been a reality from the beginning of the MNE project. Research institutions and the Spanish Regulatory Authority have made important contributions to it as well. The participation of engineers, technicians and researchers external to the university in the definition and revision of the programme is one of the most valuable MNE's assets.

Endesa makes it possible the attendance of MNE students to an important annual event of the Spanish Nuclear Society in Madrid (the Seminar on Operating Experiences and Perspectives, where the Spanish NPPs managers expose the operation of their plants during the previous year), by means of sponsoring the simultaneous translation of the event into English. To take advantage of the trip to Madrid, Endesa invites the students to visit its Headquarters, where the future nuclear engineers have the opportunity to exchange some words with the managing director of Endesa's Nuclear Division and a guided visit is arranged to the Generation Control Center (Figure 2).



Figure 2. Images of MNE students in their visit to ENDESA and during a Seminar on Operating Experiences and Perspectives. Left: Seminar of Spanish Nuclear Society in Madrid in 2015. Right-bottom: visit to Endesa Headquarters the day before the Seminar. Right-top: visit to the Generation Control Center during the visit of 2016.

Endesa and ANAV (the operator of Ascó-1, Ascó-2 and Vandellòs-2 power plants) provide lecturers for specific topics in the course on *Management of Nuclear Power Plants*.

The list of companies involved in the Programme includes: Nuclenor (a company participated by Endesa that operates a BWR plant in Santa Maria de Garoña), ENUSA (a publicly traded Spanish company for design, manufacture and supply of fuel), ENRESA (a public company in charge of the safe management, storage and disposal of the radioactive wastes produced in Spain), ENSA (a State owned company specialized in the manufacturing of heavy equipment), Tecnatom (advanced engineering), IDOM (engineering company), Westinghouse and AREVA. These companies participate in different ways, either facilitating that their professionals lecture some specific topics, opening internship positions, or offering guided visits to their facilities (see Figure 3).



Figure 3. Images of some of the visits of the MNE students to industrial facilities.
Top (left-to-right): Vandellòs-II NPP, Tecnatom Headquarters, Vandellòs-I graphite-gas reactor being decommissioned by ENRESA. Bottom (left-to-right): ENSA factory in Santander, ITER site in Cadarache, José Cabrera NPP being dismantled by ENRESA.

The list of external participants includes lecturers from CIEMAT (the public major Spanish research centre), who lecture in the area of structural materials for nuclear plants and material degradation, but as well in other topics related with the activities of the centre, like neutronics and severe accident phenomena or nuclear fusion. For the elective course on Fusion Technology, the MNE has had the support of professionals from F4E and researchers from CEA and the Max-Planck-Princeton Center for Plasma Physics.

Last but not least, the Master has the invaluable collaboration of the Spanish Regulatory Authority (CSN). Technicians from this institution lecture some topics related to Nuclear Safety and Regulations. Moreover, the Argos Chair, sponsored by the CSN, offers fee waivers to the students

5. INTERNATIONAL PROJECTION

Since its beginnings, the MNE is embedded in EMINE [2], the European Master in Nuclear Energy (European Institute of Technology [4], KIC InnoEnergy). Part of the academic program of

the MNE is offered as well in the framework of EMINE. The students of this European master choose between UPC and KTH (Sweden) for their first year and then move to France (Grenoble INP or ParisTech) for their second year [5]. In the summer between the two academic years, students gather for a summer school in Grenoble École de Management.

KIC InnoEnergy is an European company for innovation, business creation and education in sustainable energy. It is one of the so-called Knowledge and Innovation Communities created by the European Institute of Innovation and Technology (EIT).

The EIT was set up in March 2008 by the European Parliament and Council with the aim to:

- Contribute to the competitiveness of Europe, its sustainable economic growth and job creation by promoting and strengthening synergies and cooperation among businesses, education institutions and research organisations.
- Create favourable environments for creative thoughts, to enable world-class innovation and entrepreneurship to thrive in Europe.

KIC InnoEnergy is a consortium of top European players from Industry, Research, Universities and Business Schools, with 27 shareholders (UPC among them) and additional 160 associate and project partners (Figure 4).

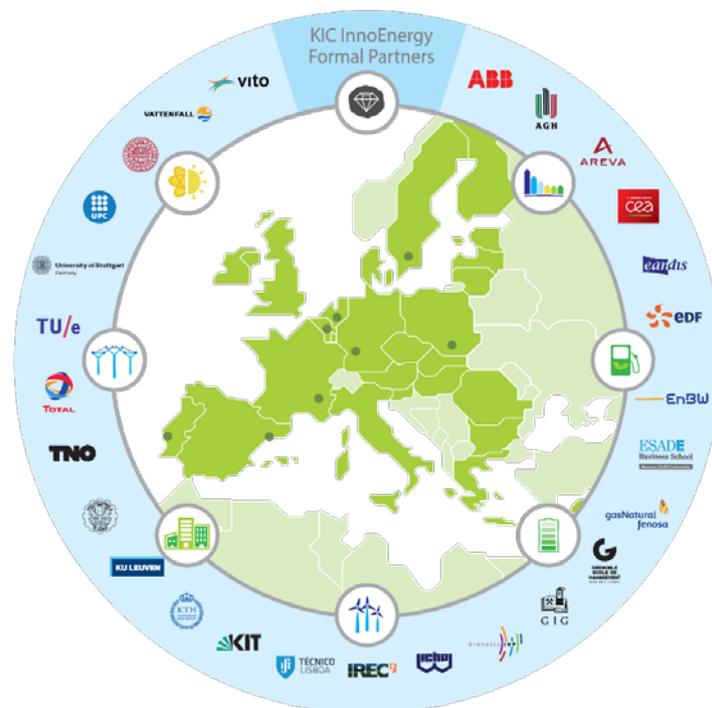


Figure 4. Kic InnoEnergy as an European network.

KIC InnoEnergy Master School is running seven Master programmes in sustainable and low carbon energy that offer a combination of engineering and entrepreneurship. EMINE is one of these programmes; all of them have international mobility as a common character:

- Students take courses in two different universities and countries.
- They get a training in innovation and entrepreneurship during the summer school
- Eventually students start an internship with one of KIC InnoEnergy partners.

The participation of UPC in EMINE has reinforced the links between this university and the other institutions participating in the European Programme, and has placed the UPC in a visible place within the international community of higher education on nuclear engineering.

The support of KIC InnoEnergy has allowed to develop a series of activities that otherwise wouldn't be possible. The continuous program reviews and improvements requested by KIC InnoEnergy have forced the MNE at UPC to sharpen the saw, and have reinforced the self-demanding attitude of the master's faculty, thus improving the quality of the Programme.

In what concerns the daily development of the master, EMINE and MNE students share the classroom and courses. Having EMINE and MNE students together creates a good working atmosphere, while allowing the future engineers work in a multicultural and international environment.

6. SHARPENING THE SAW

MNE is in continuous evolution. Self-criticism of the teaching staff at UPC, the constant interaction with our industrial partners, the contact with other EMINE partners, which leads to the adoption of best practices, and the requirements of KIC InnoEnergy, all these elements combine to boost the continuous improvement of the contents and learning methods.

Continuous adjustments are done on the contents of the courses. For instance, in the course on Systems, Components and Materials, a couple of relevant actions have been undertaken:

- The module on Systems (Tecnatom) has now a sharper focus on a limited number of systems; nevertheless, all the information given in previous years is made available to the students, so that they can use it in the assignments of the course on Management of Nuclear Power Plants.
- The module on Materials, mainly lectured by CIEMAT, has been made more attainable for students: whereas all the written information is still supplied to the students, lecturers pay more attention to the basic and crucial aspects.

An effort has been recently done to improve the exercises proposed for the course *Management of Nuclear Power Plants*. These exercises aimed to be as close as possible to actual engineering activities, e.g. analysing the suitability of the performance of any interface, designing a system, or specifying a component.

The exercises prepared following this general guideline were studies involving all the steps needed in design activities. Concepts like Design Basis, Reference Documentation or Traceability were reinforced by its use. The review of lists of systems in order to establish the impact of any design modification on their function was usually considered in the exercises. Should the exercise involve any equipment supply, the specification for it had to be prepared by the students.

Although the general guideline is still valid, self-criticism and analysis of student's results have driven the evolution of these assignments. Students still work in teams (3 people is the standard), but an increasing number of questions have to be answered individually. Teachers prepare questionnaires and wrap-up sessions bearing in mind the contents of other connected courses (not only MNPP). Each group works as a small technical office and (although the instructor is the ultimate advisor) leadership and making value judgments are skills often stimulated. Technical meetings and debates are simulated and practiced and the response of students is extremely positive since they really try to solve the problem that is posed. Debates are also used to develop other skills like summarizing, conducting a meeting or writing down the minutes.

7. CONCLUSION

The Master's degree in Nuclear Engineering from the Universitat Politècnica de Catalunya was born with a clear industrial vocation. Students develop a strategic view of the nuclear industry and the ability to formulate problems and make decisions, acquire the competencies needed to manage the projects that are run within a company, and cultivate the sense of responsibility which is at the basis of the Safety Culture.

The involvement of Industry and the Regulatory Authority has been essential in the definition of the master's programme. The contents of the program are being continuously improved with the help of our industrial partners.

The use of active learning, PBL and team work activities all along the programme help the students not only achieve the learning objectives but also acquire a number of soft skills valued by industry. This way the master contributes to prepare the future professionals the society needs.

UPC is committed to the quality of education; specifically, the MNE's faculty is highly motivated for continuous improvement. In this line, among other actions, transversal and course projects are being rethought, in line with the requirements of KIC InnoEnergy.

After the launch of its sixth edition, the Master's degree in Nuclear Engineering UPC-ENDESA is a consolidated programme with a solid international projection and an accredited quality.

REFERENCES

- [1] MNE web page at UPC. <http://nuclearengineering.masters.upc.edu/en>
- [2] EMINE web page. <http://www.kic-innoenergy.com/emine/home/>
- [3] F. Reventós et al., *Project-Based Learning in the Master's degree in Nuclear Engineering at BarcelonaTECH. Experience gained in the area of Management of Nuclear Power Plants*. 40th Annual Meeting of the Spanish Nuclear Society, Valencia, 2014.
- [4] EIT institutional web page. <https://eit.europa.eu/>
- [5] B. Cabon et al. (2016), *European Master in Nuclear Energy (EMINE). When Academy and Industry Meet*. NESTet 2016 (European Nuclear Society). Berlin, May 2016. In proceedings.