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Engineering education towards sustainability

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Abstract

The traditional systems have been studied in an isolated mode, seek to respond to a specific need and deal with a restricted set of variables. The targets established for energy efficient systems and energy sustainability imply that new systems are more comprehensive and combine the various individual systems. This new topology requires a new kind of engineering professionals provided with new skills. New engineering professionals need to have not only a set of deep capabilities in a specific area, but also more comprehensive proficiencies that allow them to understand how to integrate their particular system into a wider functional system. This paper addresses some challenges and issues posed to Higher Education institutions and to engineering professionals of the future.

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Keywords: Engineering education; engineering professionals; Higher Education; sustainabiliy

1. Introduction

Nation's development has been based in energy consumption. High population of developing countries causes a faster growth than that of already developed ones. This means that when these countries want to reach a higher state of development, the amounts of energy and resources needed are enormous. Besides, huge amounts of effluents, as

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well as of wastes, will be generated causing the need to use much more efficient and clean technologies. Thus, strategic planning is fundamental to achieve a sustainable growth.

Energy needs can no longer be only based on fossil energy, due to scarcity and environmental issues. Consequently, the associated emissions and environmental impacts are driving scientists and decision makers towards both a new model of development based on renewable energy systems, as well as on more efficient energy systems. However, both have brought new challenges. This is the case of: 1) the intrinsic unpredictability that is characteristic from a significant part of renewable energies imposing that only a low percentage of renewables is used, because the present electric paradigm is based in control; 2) the new appliances that have higher efficiency but are now nonlinear loads, because of the introduction of electronic controllers, causing negative impact on the electric energy quality.

These examples show that renewability does not necessarily mean sustainability. Every new solution that has the advantage of being environmentally friend also brings new problems that need solution. On the other hand, the non-renewable energies cannot be considered the enemy, as their total elimination from the actual energy system cannot be achieved without a deep change of both human behavior and of the energy system. The whole system has to be analyzed in a life cycle thinking perspective, where non-renewable energy sources must be considered as one essential piece to supply the failures of the renewable sources, and all the appliances that are developed to reduce the energy consumption are submitted to deep analysis of their impacts. Therefore, this new model of development relies on a new class of environment and engineering professionals, who are able to relate their particular expertise with all the other areas involved, and to understand the impacts of such systems.

It is now the time to explore concepts and emerging technologies in a collaborative way, bringing together engineers, researchers, decision makers and professionals from different areas. In fact, we can perceive that new and tighter targets towards sustainable development have been set by several countries, as from the Paris Agreement in December 2015 [1]. However, no rules were established and it was left to each country the path to reach them, as it is a sensitive matter. Thus, more than ever, it is critical to educate professionals who are able to plan truly sustainable systems. This challenge is a huge problem, which is essentially due to three factors: less students applying for engineering courses; lower quality of the incoming students and highly focused degrees in a specific area, as a result of the reduction in class hours. The actual education paradigm of engineering professionals relies on highly multidisciplinary profiles.

This paper presents some challenges and issues posed both to teachers and to students that will be later engineering professionals.

2. Higher education

Higher education is considered as a key factor and essential for the future success of people in modern society. Its implication is well recognized despite the high cost for each country. Indeed the number of people with this level of education has increased dramatically over the past 50 years. This increase in students has, however, brought new challenges not only to national economies but also to educational systems [2]. In fact, more traditional and teacher-cantered methodologies have proved to be inefficient when applied massively [3]. This unacceptable situation led not only to an adjustment in teaching strategies, but also to a greater focus on students and teaching / learning methods [4,5]. The Bologna process brought with it a reorganization within universities to improve educational resources, [6] but also a tendency to shorten the duration of degrees and to focus them on a very limited area of knowledge [7,8]. Thus, these new degrees have become very specific, with a high level of specialization and a reduced scope. This new scenario has brought advantages and disadvantages, particularly in the case of engineering education [9].

On one hand, this strategy makes it possible to keep technological and educational development processes closer to each other [10] since the narrower the scope, the easier it is to achieve a higher level of knowledge. On the other hand, the aforementioned strategy has several disadvantages, such as the reduction of skills in terms of abstraction to deal with more realistic and complex models, the lack of ability to deal with *multidisciplinary* problems [11] or even the ability to generalize, ie., the ability to associate the structure of several systems. The latter skill assumes special importance in engineering programs given the fact that solutions to modern problems are essentially multidisciplinary.

3. Sustainability in higher education

The teaching / learning concepts of Control Systems Engineering are presently of particular importance because they are based on their development and application in systems that are intended to be increasingly sustainable. The most quoted definition of sustainability refers:

"*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*." [12]

A more strict, technical interpretation for engineering systems may be as follows:

"A sustainable system is one that consumes the resources strictly necessary to obtain the desired effect".

It should be noted that this new definition highlights two main factors. On the one hand it is sufficiently broad to be applied to any system, e.g., (home appliance, building system, biological system, educational system, health system, etc.). On the other hand, it shows the need for *optimization*. The optimization of a variable in a system implies its *control*. In turn, the control leads to the development of closed-loop mechanisms that allow the controlled variable to remain even in the presence of disturbances.

Therefore, automatic control is in the basis of sustainability because it allows to optimize the systems consumption. This is a particularly important issue in the European Union (EU), since the sustainability-related objectives of each country are systematically revised, being more demanding. A very visible face of this effort was placed on cars that now exhibit a good performance along with very low pollution rates. However, these results were only possible through the massive use of sensors, actuators, information, and computation. These are highly *multidisciplinary* systems that include mechanics, electricity, electronics, chemistry, computers, among others. Older cars have no electronic control units or lines of code, but now even low-end cars can include 30 to 50 microprocessors governing windows, doors, dashboard, seats, and so on, in addition to powertrain and vehicle dynamics. Luxury cars can have more than 70 and as many as 100 microprocessors. Analysts seem to agree that a modern premium-class car probably contains close to 100 million lines of software code [13].

The next trend will cover buildings as they account for about 49% of the world's energy consumption. Away from the ideal situations of the past, the so-called Zero net Energy Building (ZEB) and Nearly Zero net Energy Building (NZEB) are real demonstrations of this. Recent legislation imposes ever more demanding rules on the performance level of new constructions to be built. As with cars, the new buildings will be multidisciplinary and very complex.

In the past the project was done by independent layers: electricity, water, telephones, alarm, central heating, etc. This methodology of design is no longer suitable for the design of high-performance buildings, where the various layers need to be integrated into a global state observation and control platform. To do this, and as previously mentioned, we must use the resources exactly necessary to obtain a desired effect. Take lighting as an example. For proper lighting, closed-loop control of this variable is required, i.e. closed-loop (mathematical) concepts are required. It is also necessary to control power (Power + Power Electronics Systems). Thus, the bulbs will provide the exact amount of light to compensate for the one that is not provided naturally. A more complex system would involve controlling room's blinds. Air renewal control would measure indoor air quality (chemical/environmental engineering) and renew air as needed (HAVAC - mechanical engineering). Inner (winter) and outer (summer) blinds can be provided according to the thermal (mechanical) requirements. The central heating should be used in each room according to the specific needs of each location. Each room must have a control that depends on its use and should identify the presence of users. Infrastructures necessary for monitoring and observing the status of each parameter should be provided (civil engineering). The whole system is interconnected by an information network (computer science). All this system should have a management component (industrial management and engineering).

As shown, future engineers must receive essentially multidisciplinary education.

4. Sustainability of higher education

Much has been written about the requirement to adapt teaching both to the new generation of students and to the more recent technical needs. It is a global problem of sustainability of higher education institutions as a whole. Jan Gulliksen, dean of School Computer Science and Communication at KTH said in the European Convention of Engineering Deans (ECED), Universities are at risk from several issues: (i) They are not sufficiently engaged with the external world and focus too much internally; (ii) They have to make their selves more resilient in order to survive.

Kamp [14] summarized what trends in engineering deans in Europe care about most as follows: (1) crossing disciplinary boundaries; (2) societal impact instead of individual achievements; (3) T-shaped professionals; (4) *interdisciplinarity*; (5) different engineering profiles; (6) students as change agents; (7) integration of skills in disciplinary curricula; (8) makerspaces societal and industrial engagement.

As shown, higher education institutions need to be extremely resilient in order answer these new challenges.

5. Conclusion

Higher education is now facing new challenges. On one hand, the new generation of systems (e.g. buildings) have increased complexity in order to answer sustainability issues. On the other hand, programs duration has been shortened, and the contact time student – teacher is diminishing progressively. Even worse, there is an ever-decreasing number of students who opt to graduate in engineering. This situation poses new challenges on higher education institutions. They must take advantage of their resilience.

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References

[1] UNFCCC (2015). Annex: Paris Agreement and Decision 19/CP.21 Extension of the Mandate of the Least Developed Countries Expert Group. Report of the Conference of the Parties on Its Twenty-First Session, Held in Paris from 30 November to 13 December 2015 Addendum Part Two: Action Taken by the Conference of the Parties at Its Twenty-First Session (FCCC/CP/2015/10/Add.1) and (FCCC/CP/2015/10/Add.3).

[2] Schofer, E., Meyer, J.W. (2005). "The worldwide expansion of higher education in the twentieth century." *American Sociological Review*, 70.6 (2005): 898-920.

[3] Biggs, J. (1999) "Teaching for quality learning at University". Buckingham, UK: Open University Press.

[4] Felder, R. "How to Improve Teaching Quality", Quality Management Journal, 6(2), pp. 9-21, 1999.

[5] Ramsden, P. (1987) "Improving teaching and learning in higher education: the case for a relational perspective." *Studies in Higher Education*, 12.3(1987): 275-286.

[6] Shearman, R. (2007) "Bologna: engineering the right outcomes", *International Journal of Electric Engineering Education*, 44.2(2007): 97-100.

[7] Heitmann, G. (2005) "Challenges of engineering education and curriculum development in the context of the Bologna process", European *Journal of Engineering Education*, 30.4(2005): 447-458.

[8] Klemeš, J.J., Kravanja, Z., Varbanov, P.S., Lam, H.L. (2013) "Advanced multimedia engineering education in energy." *Applied Energy*, 101 (2013): 33-40.

[9] Williams, B.R. (2007) "Engineering education, accreditation and the Bologna declaration: a New Zealand view." *International Journal of Electrical Engineering Education*, 44.2(2007): 124-128.

[10] Aslan, S., Reigeluth, C.M. (2013) "Educational technologists: leading change for a new paradigm of education", *TechTrends*, 57.5(2013): 18-24.

[11] Vega, G., Schlichting, L., Ferreira, G., Felgueiras, M. C., Fidalgo, A., Alves, G.R. (2015) "A remote lab for programmable system-on-chip", Demo Track, within the EXP.AT'15 conference, Ponta Delgada, Azores, Portugal, 2-4 June, 2015.

[12] United Nations, World Commission on Environment and Development (1987). *Our Common Future*. Oxford: Oxford University Press. 27. ISBN 019282080X.

[13] Charette, R.N. (2009) "This car runs on code." *IEEE Spectrum*. 46. in https://spectrum.ieee.org/transportation/systems/this-car-runs-on-code (Accessed at April 2017).

[14] Kamp, A. *Engineering Education in the Rapidly Changing World - Rethinking the Vision for Higher Engineering Education*, TUDelft, pp. 92 ISBN: 978-94-6186-609-7