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Modernising and Rationalising the First Course in Power Systems on the Island of Ireland

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Abstract-- The two largest Universities on the Island of Ireland both have significant power system activities. As part of a major all-island initiative these two groups are working more closely on joint research and educational activities. Here the first courses on power systems in the two institutions are described as part of a process which is planned to bring more co-ordination between the power system activities on the Island of Ireland.

I. Introduction

The Power Systems Engineering research groups at University College Dublin (UCD) in the Republic of Ireland and at The Queen's University of Belfast (QUB) in Northern Ireland have successfully collaborated over many years. This collaboration has mainly focused on joint research projects, shared PhD students, etc. Very recently, Power System Engineering in both institutions was jointly awarded a major €4.5M ($6M) research grant for energy research. This research collaboration is, therefore, set to grow and prosper in the future. During the many interactions between the two groups there has been much discussion on developing and delivering undergraduate and graduate level courses. These discussions have been particularly intense over the past number of months driven by two major developments. (1) Positive political developments on the island of Ireland have resulted in the development of an all-island energy market. This involves a single electricity market on the island of Ireland, requiring more co-ordinated planning and operation of the two power systems. (2) In the Republic of Ireland there is a determined effort to establish a formal fourth level educational system with the development of graduate level courses. Electrical Engineering in both QUB & UCD are actively involved in developing an All-Island Graduate Programme in Energy, and in Power Systems Engineering in particular. As part of these developments and as part of our continuing efforts at collaboration there is a clear need to understand the undergraduate power systems education in the two institutions, to learn from one another and to co-ordinate our efforts wherever it is appropriate.

The invitation to present at the Panel of the First Course in Power Systems was received by both UCD and QUB. We, therefore, decided it would be appropriate for us to submit a joint paper and presentation comparing and contrasting the First Courses in power systems in both institutions.

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II. The Queen's University of Belfast

Queen's University offers both a Bachelor of Engineering (BEng) degree in Electrical & Electronic Engineering and a Master of Engineering (MEng) degree in the same topic. The BEng degree lasts for 3 years, while the MEng course includes an additional year. The two courses are common for the first 2 years, and based on academic merit and student choice students then follow either the BEng or MEng pathway in their final / penultimate year. At Stage 1, students complete 12 compulsory modules across various aspects of electronics and electrical engineering, along with a grounding in mathematics, design and innovation. Typically, such a module will consist of 20 x 1 hour lectures, 10 x 1 hour tutorial classes and 3 x 3 hour laboratory sessions, coupled with 33 hours of private study.

In the electrical power pathway of the course, all students must complete the Stage 1 module 'Electric Power 1'. At subsequent stages of the course, students have increasing freedom to specialise in areas of their interest. At Stage 2, two courses are offered (Power Systems 2 and Electrical Machines 2), at Stage 3, three courses may be selected (Electric Power 3, Power Systems 3 and Power Electronics 3), while at Stage 4 there is a single, doubly-weighted course (Energy Systems 4). The Electric Power 1 course itself runs in the second semester by which time students should have gained experience in basic circuit analysis, phasor representations, etc. (as part of the module Electric Circuits 1) and Coulomb's law, Gauss's law, Faraday's law, etc. (as part of the module Electrical Engineering Principles 1).

At Queen's University, the traditional 'electrical engineering' course at Stage 1 had been focused on the theory of electrical machines and their design. Electrical machines considered during the course included synchronous machines, induction machines, reluctance machines and the transformer. For each topic, equivalent circuit models were developed, equipment performance characteristics were calculated, construction aspects discussed and real-world applications alluded to. The result was a highly mathematical course (in relation to other Stage 1 modules) which required students to be competent with 3-phase theory, circuit analysis, vector manipulation, etc.

As a consequence, ‘power systems’ as a distinct area of interest, was not formally introduced until Stage 2.

A. Designing the QUB Module

A number of linking factors lead to a re-assessment of the Stage 1 course:

- The university adopted a semesterised modular structure instead of the traditional ‘year-through’ system. A knock-on effect of this decision was that options were introduced into Stage 2. Consequently, students could decide not to pursue ‘electrical’ engineering options further, e.g. Power Systems 2 and Electrical Machines 2. Previously, these courses would have been compulsory.
- The Stage 1 course provided a good foundation for students wishing to pursue a career in electrical machine design (supplemented by courses at Stages 2 & 3, of course). Consequently, minimal focus was placed on device applications, aspects of control, or how the machines impact on power system stability, etc.
- Stage 1 students found the existing course mathematically challenging, while also requiring a good working knowledge of electric circuit analysis, a.c. theory, electrical principles, etc. Commonality between equivalent circuits of different machines, similarity of testing and manufacturing procedures, etc. could be seen as confusing rather than reinforcing (of knowledge).
- Minimal linkage to Stage 2 course in power systems. Under the new modular system, students could graduate with a degree in Electrical & Electronic Engineering never having encountered how electrical power is generated in a conventional power station, why frequency and voltage are controlled, etc.
- Growing relevance of issues such as global warming, renewable generation, the future for nuclear fission, introduction of electricity market structures, etc. within the power systems field. These were seen as discussion topics that could enthuse students, but were not addressed in the (compulsory) Stage 1 course.

B. Course Content

As a consequence, a new Stage 1 course was created, keeping some of the existing Electrical Machines 1 course, while also introducing material allied with power systems engineering. A short summary of the new structure follows:

Power system operation: unit commitment, growth in electrical demand, distribution & availability of resources, electricity market operation.

Load-frequency control: turbine-governor control, economic dispatch / free governor control, tie-line connections, emergency frequency control, system reserve and load shedding.

Three-phase systems: 3-phase generation, 3-phase vs. single-phase systems, star-delta connections.

Synchronous machine: theory of rotating fields, equivalent circuit model + open- and short-circuit characteristics, synchronisation, machine construction, pumped storage.

Electricity transmission: interconnected power systems, overhead lines + cables construction, short-line transmission model, load flow, d.c. approximation.

Transformer: ideal vs. practical devices, equivalent circuit model and measurement of parameters, device construction, 3-phase transformers.

Electricity generation: energy sources (fossil-fuels, nuclear, solar, wind, etc.), thermal power station operation, governmental (renewable) targets and incentives.

Has the conversion process been a success? One measure is that almost 50% of students in their final year (as part of a degree in electrical & electronic engineering) choose to select their major (year-through) project in the general area of power systems / electrical machines, only one of 6 major course themes. This is probably due to the increased public and political focus on ‘energy’. However, while the traditional ‘electrical machines’ course may have turned some students away from a career in power engineering, it is hoped that the new programme has encouraged and enlightened them about how rewarding a power engineer’s job can be.

In the UK, under the guidance of the Institution of Engineering and Technology (IET) a Power Academy has recently been established (2005). It was recognised that the power industry is a largely ageing population, and in an increasingly dynamic industry there is an increasing shortfall of undergraduates studying electrical engineering and allied subjects. The Power Academy consists of 6 participating UK universities (one of which is Queen's) and 15 employer partners (ABB, e-on, National Grid, Siemens, etc.). Students are offered attractive scholarships during their degree studies, and can spend their vacational placements at individual company sites and/or attend Power Academy seminars / conferences. A similar scheme to encourage postgraduate researchers, with the same participants, is also in development.

III. University College Dublin

UCD offer four year degree programmes in Agricultural & Food, Chemical, Civil, Electrical, Electronic and Mechanical Engineering. Until last year each department was responsible for organising and delivering courses for their own particular programme and the curriculum was very rigidly specified with little or no flexibility for students. Electrical & Electronic Engineering offered foundation level courses that were a mandatory part of the curriculum for virtually all the degree programmes.

UCD is now in the midst of an enormous change. Both the structure for educational delivery and the organizational framework have been revolutionised. UCD is well on the way to having a fully semesterised and modularised teaching structure, very similar to what exists in the US (and now at Queen's). While historically courses were delivered over an entire academic year and virtually the only means of assessment was the end-of-year examination, UCD is now embracing fully modern concepts of structured university education. Belatedly, all across the board, UCD is designing and building modules on the outcomes based approach to learning and structuring our assessment methods to achieve those outcomes.

A deeply rooted philosophy on education in Electrical Engineering and more widely across all engineering disciplines in UCD is that teaching of engineering should be based on the underlying scientific principles. UCD encourage a step-by-step first principles approach to problem solving and apply rigorous mathematical expression to all subjects. This philosophy will not change in the current revolutionary environment.

A. Designing the UCD Electrical Engineering Module

Electrical Engineering module to be delivered to students in Stage 2 is designed in the context as described above. In an environment of scarce resources, where it is necessary to get maximum utilization and flexibility from individual modules, this particular module would be core for students who are on the Electrical, Electronic and Mechanical Engineering degree programmes. For students of Electronic and Mechanical Engineering it might well be their only exposure to Electrical Engineering (Power System Engineering). A further design constraint is that students would only have a very small exposure to circuit analysis and a similarly small exposure to basic electromagnetics in the Stage 1 Physics module.

B. Course Content

The first course in power systems is an important course as without a solid understanding of the fundamentals of electrical engineering, the later more advanced courses will be extremely difficult. It takes the form of a basic course in electrical engineering covering wide ranging topics from active and reactive power to rotating magnetic fields. At UCD the first course in power systems is offered to electrical and electronic engineering undergraduates at Stage 2 and to mechanical engineering undergraduates at Stage 3.

Previously, the students will have completed courses in physics, mathematics, circuit theory and electromagnetics, equipping them with the knowledge required to deal with topics such as 3-phase circuits or rotating magnetic fields. This course is considered the first course in power systems as it considers the principles taught in earlier courses and applies them to the power system, i.e. issues involved with the generation and transmission of power. The course covers a number of the important aspects of power systems. A short run down of the main topics covered is given in the list below.

Energy Conversion: introduction

Power and energy in a.c. circuits: phasors, active and reactive power

Magnetics: Ampere's Law, Faraday's Law, B-H characteristics

Transformer: Ideal and equivalent circuit model

DC machine: Commutation, series and shunt connection

Polyphase circuits: 3-phase generation, star delta connections

Rotating magnetic fields: synchronous and induction machines

Significant laboratory content is associated with the course. This is an important aspect of the module structure and is closely co-ordinated with delivery of the lectures. There is no software component to this course, as this is reserved for a later course in power systems.

At the end of the course it is expected that students will have a good understanding of the fundamental principles of electrical engineering and an appreciation of their relevance. The course covers a lot of material spanning electrical machines, circuit theory and electromagnetics. The one binding feature is the application and relevance of the topics to power systems, and furthermore, it is hoped that through increased focus on 'energy' students will appreciate the importance of power systems right from the start of their power engineering education. Further courses in power systems and electrical machines are offered at Stages three and four. All of these courses rely heavily upon the successful delivery of this first course.

IV. DISCUSSION

The QUB first course in Power Systems has been running now for four years while the UCD first course in power systems will only begin in January 2007. Therefore they are at different stages of their evolution. In addition the student intake in Republic of Ireland tends to have a broader educational background. These differences along with student options go some way to explaining the obvious differences in course content. The next six months will be an interesting and useful period to further compare and contrast the two courses.

Both UCD and QUB as part of their recent research funding successes have obtained some support to encourage undergraduate students into the area. These Parsons Awards will be used to further stimulate interest in the student body in Power Systems Engineering.

V. CONCLUSION

There is substantial evidence from the electricity industry on the Island of Ireland that the needs for power systems graduates far outstrip supply. Falling student numbers, dwindling resources are a further threat to the electricity industry on the island of Ireland. By acting together, where pragmatic, at all levels UCD and QUB are determined to develop a successful all-island power systems education and research activity. The first place to start in this process is the first course in power systems.

VI. BIOGRAPHIES

Jerry O'Dwyer is a lecturer in the School of Electrical, Electronic and Mechanical Engineering at University College, Dublin where he has been teaching since 1981. He is the holder of numerous patents in the area of electrical machines and has published on the subject.

Damian Flynn (M'96) is a senior lecturer in Power Engineering at The Queen's University of Belfast. His research interests involve an investigation of the effects of embedded generation sources, especially renewables, on the operation of power systems. Further work is focussed on the operation and simulation of power systems, examining issues such as reserve management and the causes of system instability. He is also interested in the areas of advanced modelling and control techniques applied to power plant.

Andrew Keane (S'04) received a B.E. degree in electrical engineering from University College Dublin in 2003. He is a lecturer in the School of Electrical, Electronic & Mechanical Engineering, University College Dublin. His research interests include power systems planning, distributed generation and distribution networks.

Mark O'Malley (S'86-M'87-SM'96) received B.E. and Ph. D. degrees from University College Dublin in 1983 and 1987, respectively. He is currently the Professor of Electrical Engineering at University College Dublin and director of the Electricity Research Centre with research interests in power systems, control theory and biomedical engineering.