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Issues affecting power engineering undergraduate education in Australia

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Recent changes to the electric power industry through deregulation and restructuring have had a considerable effect on power engineering education internationally. A number of Australian universities have also noticed a decline in the number of students interested in power engineering subjects, leading to the fewer graduates with power engineering knowledge. With a reduction in graduates and a perception of an aging workforce a shortage of suitably qualified power engineers for industry may be imminent. This paper provides discussion on the current status of university power engineering education within Australia and includes results from a recent Australia-wide survey of the university and industry sectors of electric power engineering.

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ISSUES AFFECTING POWER ENGINEERING UNDERGRADUATE EDUCATION IN AUSTRALIA

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Abstract
Recent changes to the electric power industry through deregulation and restructuring have had a considerable effect on power engineering education internationally. A number of Australian universities have also noticed a decline in the number of students interested in power engineering subjects, leading to the fewer graduates with power engineering knowledge. With a reduction in graduates and a perception of an aging workforce a shortage of suitably qualified power engineers for industry may be imminent. This paper provides discussion on the current status of university power engineering education within Australia and includes results from a recent Australia-wide survey of the university and industry sectors of electric power engineering.

1. INTRODUCTION

Over the past decade power engineering has suffered a poor profile leading to less interest from high school and university students. This can be partially attributed to industry deregulation where utility organisations trimmed down their engineering expertise to reduce operating costs and large numbers of professional redundancies became apparent, creating a reasonably unstable career path for those considering entering the profession [1]. Combined with the perception that the industry is "old fashioned" as compared to the information technology and telecommunications industries, it can be realised why high school and university students may not be attracted to a power engineering career.

Such external pressures affect the viability of power engineering schools at universities through reduced enrolments in power engineering specialisation subjects and difficulties in finding postgraduate research students to work in the power engineering discipline. In return a reduced number of students with power engineering specialisation will be available to the power industry to fill vacancies. Without a renewed effort by industry, professional organisations, or a new cooperative body, these issues will create a downward spiral which may see the closure of some power schools, eventually leading to a shortage in technical expertise. If the current situation is simply left to natural forces it will be to the detriment of the power engineering discipline.

In 2002 the Institution of Engineers, Australia (IEAust) initiated a study into the manpower requirements of electrical power engineering within Australia in order to develop a clearer understanding of concerns suggesting a looming shortage of electrical power engineers. The study was undertaken by the School of Electrical, Computer and Telecommunications Engineering at the University of Wollongong. The possible reasons initially suggested for such a shortage included

(i) an aging workforce of qualified electrical power engineers,
(ii) a reduction in the quality and numbers of electrical power engineering graduates,
(iii) a declining relationship between industry and universities with regard to research activities, and
(iv) the detrimental effects of industry deregulation.

The study included two separate surveys to gather relevant information from the industry and university sectors. The surveys were designed to provide a better knowledge of the supply and demand of power engineers and also to address any ongoing issues that the power engineering discipline was facing with regards to the supply of engineering expertise.

Based on power engineering workforce numbers estimated in [2, 3] industry organisations representing approximately 35% of the Australian professional power engineering workforce responded to the survey. The sample included a good cross-section of generators, transmission and distribution utilities, consultancies, regulators, manufacturers, and larger industrial customers. The sample was perceived to be an acceptable representation of the entire power engineering discipline.

The university survey questionnaire was distributed to all of the Australian universities that had some type of electrical engineering involvement. Approximately 80% of the relevant universities responded to the questionnaire, with all the larger power schools included in the survey sample. In addition one university from New Zealand participated in the study.

This paper reports on the outcomes from the university sector questionnaire, and more specifically on the undergraduate requirements identified by the study. A brief overview of the outcomes from the industry survey is also discussed to provide a backdrop to the university issues.

2. INDUSTRY SURVEY

Results from the industry survey will not be discussed in detail in this paper however some of the key issues identified are presented here.

According to the study industry at present is being faced with the prospect of an aging workforce that is fast approaching significant numbers of retirements. Commentary from the industry survey respondents suggests the ability to find suitable experienced power engineers to fill vacancies created by retirements is becoming difficult and in some cases already quite problematic. The organisational age profiles of most industry survey respondents illustrated a strong lean towards the upper age group of 45-55 years of age and insufficient numbers of younger, less-experienced engineers. Organisations also indicated that as a whole the industry is in an era of growth of their manpower resources, calculated to provide a total growth of approximately 17% from 1998 to 2008.

Another major issue highlighted in the industry study was that through the period of adjustment to deregulation, large power organisations such as electricity utilities found themselves inclined to employ consultants to cover for the loss of expertise produced by significant redundancies. However, consultants are a very static manpower source in that they are typically resourced from experienced engineers within the power engineering industry. The overheads they charge do not usually allow for the provisions of training a graduate engineer to continue to develop the consultancy workforce. The training of new power engineering graduates is typically left to utilities that have the resources to implement graduate development programmes. However, few organisations are utilising such programs due mainly to time constraints.

While some power engineering organisations receive numerous applications to fill graduate vacancies, it was reported in the industry survey that it was difficult to find graduates with extensive power engineering knowledge. Some survey respondents from industry believe this is a reflection of the "watering down" of the technical content in undergraduate degree programs. At a forum held as part of the study it was indicated that universities did not believe the technical content of their course had been significantly reduced. However, it was no longer their objective to produce a graduate with comprehensive power engineering expertise. Broadening degree structures ensures that their graduates remain employable in a wide range of disciplines, a strategy employed world-wide [4]. A reduction in the availability of mentoring for new graduates within organisations due to time constraints has also placed perhaps unreasonable expectations on graduate attributes.

The major concerns from the industry survey where that organisations were finding in difficult to attract both experienced engineers and graduates of higher quality to their organisations. The lack of experienced engineers was also highlighted by the concerns of an aging workforce and possible loss of critical organisation specific knowledge.

3. UNIVERSITY SURVEY

3.1 University survey sample

There are approximately 39 major universities spread throughout Australia. Approximately 27 universities offer degrees in electrical engineering or a similar qualification. The survey questionnaire was distributed via email to each of the 27 universities with an attached spreadsheet comprising of five sections

(i) contact details of a suitable person within each institution,
(ii) establishment of final year electrical power engineering student numbers and interests,
(iii) analysis of electrical power engineering teaching resources,
(iv) research activities, and
(v) general issues regarding electrical power engineering education.

About 80% of the selected universities responded to the survey. From the survey results it was found that specialist power engineering courses and subjects are presented at 25 of the universities that offer electrical engineering degrees. This matched the number of universities accredited by IEAust to provide four-year undergraduate electrical engineering degree programs [5]. Only one of the universities offers a degree with the terms "Electrical Power" in the title, while two others have recently abandoned the term "Power" from their degree titles. Two universities offer a three-year undergraduate engineering technology degree in electrical power.

3.2 Power engineering student numbers

Enrolments at the universities that responded to the questionnaire included a total of 1656 electrical engineering degree students in their final year of study for 2002. The number of these students at each of the universities varied greatly from university to university and included a considerable quantity of overseas students. A histogram of the number of electrical engineering students at each university is provided as Fig 1. According to student numbers telecommunications, computer engineering, electronics, control, robotics, and signal processing were all indicated as being more popular than power engineering specialisations. Power engineering was more popular than only two newer programs on offer, namely internet engineering and mechatronics. These results suggest much work is required to make power

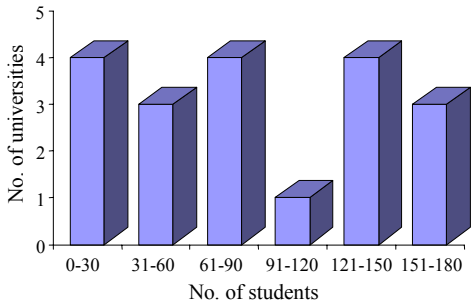

Fig 1: Histogram of the number of final year electrical engineering students at each university

specialisations more popular with students at many of the universities.

A histogram on the class sizes in the final year power specialisation classes is shown in Fig 2. It is anticipated that the seven universities represented in the left most column would currently be finding it hard to justify such small classes, and that sustainability would be uncertain in the near future.

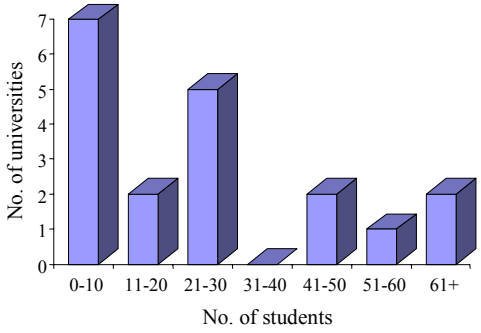

Fig 2: Histogram of the number of final year students in power subjects at each university

Although the numbers of students selecting power engineering subjects was low at a number of universities, there was a total of 512 students that would graduate in 2002 having completed at least one power specialisation subject. Approximately half of these graduating students were overseas students, and it is assumed that most will return to their country of residence on completion of their degree. These overseas students cannot be considered as seeking employment in Australia nor will they contribute significant numbers to the Australian power engineering workforce. However, such large numbers of international students will enable some power schools to sustain themselves even though local student numbers are low. The small numbers of students illustrated in Fig 2 at over 30% of universities suggests streaming into a specialised power engineering degree could not be justified at these universities.

Fig 3 illustrates the number of local electrical engineering students choosing at least one final year power engineering specialisation at each university. Without international students considered most universities have only a small number of students in the power specialisation subjects. The total number of local students from the university survey that had completed at least one power engineering specialisation subject in their final year was 267 in 2002. Considering there are some universities missing from the survey sample this number could possibly be scaled up, but only by 5-10%. It is highly unlikely though that all students completing these power specialisation subjects will continue in the power engineering field as most are completing subjects in other specialisations at the same time.

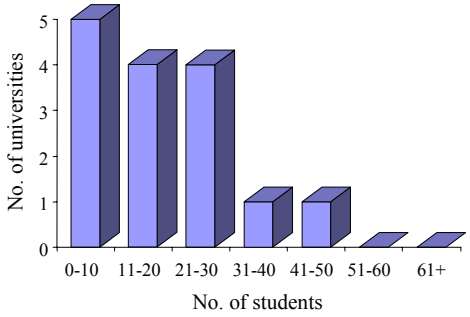

Fig 3: Histogram of the number of local final year students in power subjects at each university

According to survey results approximately 76% of students completing power subjects will graduate with an electrical engineering specialisation as opposed to computer and telecommunication, mechatronics, etc. This suggests approximately 218 local students will have an electrical engineering degree with at least a limited focus on power engineering. As mentioned previously in Section 2 the degree structures at most universities are such that these engineers could equally find employment in other electrical engineering disciplines.

It is anticipated that the number of local graduates with some power engineering background just falls below the requirements projected in the industry study. However, as it is unlikely that all these local graduates will pursue careers in the power engineering discipline much work is still to be done to ensure there are sufficient numbers to fill the graduate requirements of the industry.

University survey respondents varied in their perception of the trend in numbers of final year students in power engineering subjects. As illustrated in Fig 4 some universities no longer offer power engineering as a specialisation or as available subjects. A majority of respondents indicated that their power engineering numbers, including both local and international students remain reasonably constant. While 21% of universities indicated a growth, 16% suggested that there was a significant decrease in

power engineering student numbers. Combining the respective increase and decreases at each university overall the number of final year student numbers completing power engineering subjects is expected to decrease by approximately 30 students per annum over the period of the next five years if no new action is taken. It is perceived such reduction in numbers may lead to a shortfall in the number of power engineering graduates being produced as compared to that required by industry. The fall in numbers was attributed mainly to local industry no longer providing employment opportunities, and to a declining interest in students choosing a career within the power engineering industry.

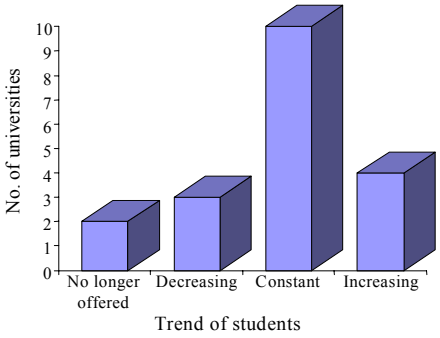

Fig 4: Histogram of indicated trends in power engineering subject student numbers

There were indications from survey respondents that the number of students selecting a more specialised five year degree, similar to that of the BSc-BE degrees studied at some universities, were becoming less popular. Students wishing to complete their degrees in the shortest possible time frame to allow earlier entry into the workforce mainly contributed this. For the higher achieving students honours programs are now incorporated into four year degrees rather than an additional specialist 5th year. It was also indicated that the increased cost of university education also contributed to the decline in numbers of students selecting the more specialised five year degrees.

3.3 Power academic profile

The number of power academics in each school at the various universities within the survey sample is shown in Fig 5. A syllabus that involves power engineering subjects will usually require at least three power academics to remain viable within the school. On this basis it is anticipated up to four schools may lose the capability to include power engineering subjects due to an insufficient number of academics. It was found that most schools only have 2-5 power engineering academics, representing less than 20% of the school in each case. Regardless of the fate of power engineering academics most electrical engineering schools will remain healthy due mainly to telecommunication and computer engineering strands.

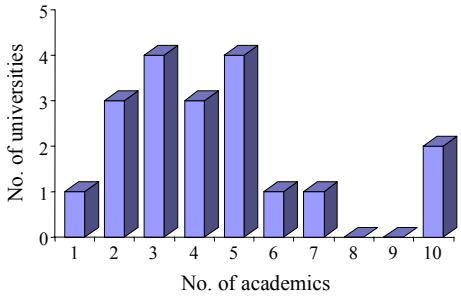

Fig 5: Number of power engineering academics within each of the universities

The dwindling numbers of experts in power engineering fields was a concern raised by industry and universities early during the study. The main reasons for this reduction in numbers is due to academics moving into non-power engineering fields and a significant number of recent retirements. Moves into the non-power engineering fields are largely due to a lack of research funding being available. Funding over the past decade has typically proven to be more forthcoming for academics in the telecommunications and computer areas.

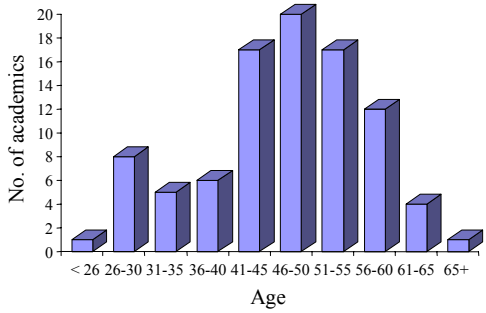

Fig 6: Age profile of power engineering academics

Fig 6 illustrates the power academic age profile for the university survey sample. The total number of power engineering academics included in the survey was 91. The median age of these power academics was slightly less than 50. If a retirement age of 60 is chosen (slightly higher than for industry engineers) up to 17 (19%) academics may be lost to retirement within five years. This may not ordinarily be a problem but the sharp peak of the age profile of academics around the median age of slightly less than 50 years suggest that there are too few younger academics entering the discipline.

To fill vacant power engineering academic positions 26% of respondents indicated that they would seek an Australian PhD student from another university, while 21% indicated they would search overseas. Only 16% stated that they would seek to appoint a power engineering academic from their own local PhD student base. Within the survey sample there were a total of 133 power engineering post graduates with about 80 being local. Two universities make up half of

the local post graduate numbers, with most universities only having one or two. There appears to be adequate numbers of power engineering PhD research students to fill future academic vacancies.

The university study also highlighted that there no longer exists the nurturing of younger academics that has historically been in place to facilitate the passing on of knowledge. This was attributed to additional university pressures, including a scarcity of resources. The knowledge base of the more mature academics is being lost as they retire at a higher rate than industry engineers, and often from schools with no intention of replacing them with another power academic. The general feeling from universities was that strong industry support is needed to prevent the demise of power engineering within schools.

3.4 Undergraduate requirements

The changing needs of undergraduate power engineering education requirements from both an industry and university perspective were investigated during the study. As with most engineering degrees, power engineering requires substantial levels of mathematics and sciences from high school. It has been reported that high school students overall are selecting less mathematics in favour of the softer sciences [6]. This is a trend that needs to be addressed for all engineering careers by better promoting engineering to high school students. Bridging programs in the early stages of university may also be an alternative to attract students who might not have sufficient background in the required areas.

Universities also need to ensure that they sustain quality teaching to continually attract students [7]. A large input from industry is required for continuation of research activities and to ensure that university resources, such as laboratory facilities, are kept up to date to allow quality teaching to be sustained. It was highlighted in the study that the topics most popularly covered by the universities only met in part the desires of industry.

As undergraduate degrees are of a broad technical base, training to develop power engineering expertise must be taken after graduation. This could be via MSc postgraduate degrees, as per the structures in the U.S.A. and U.K. [4], or via industry training through graduate development programs. In either case industry must be supportive to ensure such programs can continue to exist.

3.5 IEAust influence on degree structures

Universities in Australia undertake accreditation reviews of their degree programs by the IEAust typically on a five-year basis. As part of the accreditation universities must illustrate that the content of a four-year professional engineering degrees contains at the least, as part of the total learning experience, approximately 40% theory (mathematics, science, engineering principles, tools), 20% design and projects, 20% specialisation, and 10% engineering practice (including management and ethics) [8]. This degree structure is flexible in respect to delivery but it can be seen that more time goes in projects, management and ethics, than what was typical 20 years ago. This type of degree structure has been welcomed by industry in general across many disciplines.

The power industry survey identified that there was some concern from industry that the content of electrical engineering degrees may not contain the required background theory to prepare a graduate for a power engineering career, historically dependent on a considerable amount of mathematics and physics. However, with the IEAust degree structure it was agreed by most universities that providing an undergraduate with a specialised, in depth power engineering knowledge was not always practicable, although it could definitely be addressed at postgraduate level. There was also concern that streamlining an undergraduate into the power engineering discipline may indeed impact detrimentally on the future employment opportunities of graduates. For these reasons industry and universities, in collaboration with the IEAust, must ensure a suitable balance is obtained between theory and engineering practice styled topics in the undergraduate program.

4. THE FUTURE

4.1 Rationalisation

Australia has a high number of universities providing power engineering specialisation subjects to final year students. However, very few of these universities are able to justify an in depth program specifically on power engineering at undergraduate level. If it is proposed that industry requires a specific power engineering degree at undergraduate level than some form of rationalisation of the number of universities may need to take place to ensure that student numbers and resources required are able to be sustained.

While rationalisation has already been proposed for other engineering programs [9], it is a difficult proposition for Australian universities. The topography of population in Australia is a major contributor to this difficulty. Indeed centralising power engineering to a few major centres may turn away prospective students who would be forced to travel interstate to obtain their training. Also the competing utilities within each state typically provide

support to their local university. Such support may not be forthcoming if the research is being completed in another state. For these reasons it is perceived that rationalisation is not a suitable answer to addressing power engineering undergraduate training problems.

The high number of universities offering the electrical engineering programs can be justified by the great variety of specialisations offered in electrical engineering degree programs. The significant number of full fee paying overseas students will also allow some universities to continue providing power engineering programs regardless of the local situation provided the teaching resources are available.

4.2 Shared resources

Due to the limited number of students selecting power engineering specialisations and the extensive resources required for research and teaching, one proposal in addressing the training issues of power engineers is to share teaching resource and facilities. This approach requires extensive collaboration between universities who historically compete for students, often within the same local area. A mechanism for this approach has been run successfully in Canada [10] for a number of years with extensive industry support through the formation of a power engineering institute.

The formation of an institute should allow resources such as personnel, laboratory facilities, teaching materials, and expertise to be shared between a number of power engineering schools. This would allow power schools to remain viable and also provide a constant flow of power engineering graduates to industry. A power engineering institute may also be an avenue for collaborative research, postgraduate training, and shorter professional courses.

5. CONCLUSION

A study into a possible looming shortage of power engineers has been undertaken for both university and industry sectors. Some of the results from the university study have been presented in this paper.

Historically Australian universities have produced a reasonably steady number of power engineering graduates for industry. Although seemingly enough to fill industry graduate vacancies there is some evidence these numbers may be falling slightly if appropriate action is not taken to promote power engineering.

Universities are losing technical people at a reasonably high rate due to retirements and a scarcity of research funding. Due to low student numbers some power schools may follow. It is suggested that strong industry support is needed to prevent this. Strong support from industry for research is also required to maintain a high standard of education.

Power schools need to be diligent to ensure they are implementing innovative teaching methods and producing quality research. This is required to ensure high calibre graduates are available for adaptation into the power engineering industry.

A discrepancy between the graduates being produced and the type industry desires is evident. A forum for collaboration between universities and industry is required to address this issue. Industry and power schools depend on each other more than ever and there is need for greater cooperation to ensure the future of power engineering in Australia.

6. ACKNOWLEDGEMENTS

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