Board 91: Work-in-Progress: A Systematic Gap Analysis of the Australian Power Engineering Curriculum

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Abstract

Australia is currently undergoing a transition to a new energy model that relies on renewable and clean energy resources, as part of a global effort to combat climate change. Despite setting a target to reach net-zero carbon emissions by 2050, the energy sector continues to heavily depend on professionals who possess expertise in fossil fuels. Consequently, a significant shift is required in the necessary knowledge base and technical skills within the modern power industry. The existing knowledge and skills gap between what is taught in the higher education curriculum and what is required by the renewable energy industry is one of the prevalent issues that needs to be addressed. Australian universities now have the responsibility to equip upcoming power engineering graduates for the imminent demands of an evolving energy industry. This paper presents a systematic gap analysis (in progress) that assesses how well current power engineering curricula addresses the concerns of building a competent workforce that can resolve the technical challenges of a changing energy industry. The methodology involves collecting data from selected power system related subjects and programs at Australian universities and comparing them against responses from seasoned industry professionals through interviews. The preliminary results of the study demonstrate the specific knowledge and skills required by power engineers, highlighting the need for educational institutions to continually update and improve the curriculum framework to bridge the gap. This contribution aims to inform educators on what can be included and redesigned in power engineering courses to adequately prepare a workforce that benefits the global energy transition.

1. Introduction

The Australian energy sector is expected to make substantial changes to the way it incorporates renewable energy into existing power systems as part of global efforts to reduce carbon emissions outlined by the Paris Agreement [1]. To meet these commitments, Australia has pledged to reduce emissions by 43% below 2005 levels by 2030. Achieving these targets requires a new set of skills to build, test, and maintain upgraded electrical infrastructure and technology that revolves around renewables. Despite allocation of resources and funding towards universities and professional training programs, Australia currently faces a skills shortage and lacks a workforce that is confident and prepared to take on the challenges of a clean energy future [2]. 60,000 new jobs in energy planning and management are expected to form in regional Australia alone by 2025, with the number increasing every year. By 2025, it is projected that the construction of generation, storage, and transmission projects necessary to power cities with renewable energy will require an additional 43,000 workers [2]. With very large energy targets to hit, an equally significant effort must be made by education systems to equip upcoming power engineers with the necessary skills and knowledge to tackle the problems of an evolving industry.

For the past 30 years, university engineering faculties have been developing academic content in power engineering curricula to meet the milestones presented in the RACE 2030 E3 Opportunity Assessment: Developing the future energy workforce [3]. However, they are falling behind in courses and programs with updated content and topics, that:

- Explores various renewable energy generation techniques,
- Demonstrates how to integrate such sources with existing electrical infrastructure,

- Analyses power systems that utilize renewable energy resources for electricity generation, and
- Investigates the impacts of the distributed generation on the reliability and stability of the national energy network.

This manuscript is structured as follows: In Section 2 (Literature Review), a review of curriculum development and industry patterns in the field of energy systems is presented. Section 3 (Data Collection) describes the methods used for collecting data from industry and academia. Australian universities that offer power engineering subjects have been investigated with special attention to course learning outcomes. Moreover, 10 industry professionals, with relevant expertise, were interviewed to understand the required knowledge and skills for working in the modern power industry, as well as their views on the current state of power engineering education. In Section 4, a comparative study is conducted between the academic courses and the responses from the interviewees. This provided insight into the extent to which the current power engineering curriculum meets the needs of the industry. Finally, the contribution concludes with the implications of restructuring courses for the development of future curricula in the field of energy systems.

2. Literature Review

Previous reports and academic papers have highlighted how power engineering curricula should explore the diversity and capability of renewable energy resources available, the generation, transmission and storage of renewable power, modernized distribution networks, the pipeline of delivering electricity to consumers with careful economic and ethical consideration, and renewable power system stability and operation. While some Australian universities have been able to address majority of these topics, many are yet to integrate the content into teaching programs seamlessly - inhibiting the prospects of depending solely on renewable energy. A brief overview of research that has been conducted to encourage the study of renewables in course curricula is explored in this section, which presents a literature review of academic research into the area of renewables in Australia. From the papers studied, three areas of concern are investigated in detail, including:

- Bringing Awareness to the importance of incorporating renewable energy education in curricula,
- Common industry patterns of what renewable resources are used, employability prospects and skills required, and
- Current endeavours by the education system to prepare students for the renewable engineering industry.

2.1. Bringing awareness

Interest in studying renewables has increased drastically over the last 30 years. Before the solar boom in the 2000s research in the renewable space was limited due to the lack of scientific experts and a widespread belief that it was not a worthwhile investment. Many scientists believed that power generation via photovoltaics (PVs) would be too expensive compared to traditional methods, but the cost has decreased by more than 80% in last 15-17 years [4]. The publication, the Big Picture of Energy Generation 2030 highlighted that from 1990-2015, there was a technology at the forefront of research and design [5]. This has now brought attention to expand educational efforts with the aim of creating courses that teach students how to build and implement such technologies. It could be argued that the emphasis on solar energy-related content in the curricula has been a recent development, with a noticeable increase in attention over the past two decades.

From the example above, it is clear that a lack of awareness is a barrier to education. Other barriers include:

- Shortage of qualified teaching staff with expertise and relevant experience in developing effective teaching materials in renewable-dominated power systems,
- Insufficient inclusion of energy policies in power engineering curricula, creating difficulty in understanding real-world applications of renewable energy systems and
- Personal values, attitudes, and behaviours of educators and students towards green energy as a worthwhile future investment, which can impact the level of interest, attention and efforts given to curriculum renewal.

Educated teaching staff are responsible for providing well-organized course content and are crucial in encouraging students to enter the renewable energy space. More importantly, educators who truly believe the social, economic, and environmental importance of renewable energies for the future of sustainable systems can influence students' world values and course curricula. According to a case study conducted in Poland in 2013 [6], the priorities of a teacher can impact the extent to which sustainable development is integrated into the secondary school curriculum.

- Less than 50% of the teachers from subjects that were surveyed received some sort of training in Education in Sustainable Development (ESD).
- More than 50% of teachers who had poor understanding of ESD believed that it should not be incorporated in mandatory subjects in school.

This indicates that the majority of teachers surveyed did not believe ESD is worthwhile to be studied as a mandatory part of the curriculum, which could be extended to other countries, where lack of awareness amongst educators can affect the academic and professional pursuits of students.

Of the students that do pursue power engineering, a 2017 case study in Jordan [7] demonstrates that they are aware of the importance of renewable energy (RE) for the future but still did not understand what resources were available or how to use them. Senior students from six universities across five different engineering faculties responded to relevant questions to project their understanding in the area. The study showed that students scored well on questions:

"The total dependence on imported energy is considered a main problem in Jordan"

"(The) Future of Jordan depends on the development and utilization of available sources (renewable, oil shale, others)".

However, many misjudged how much they understood about the use of renewables in their country, scoring average for questions:

"How (do) you evaluate your knowledge about renewable energy and its utilization"

However, they proceeded to score low when asked about the available energy sources in Jordan. This lack of knowledge and awareness extends to economic factors like energy consumption and impacts employability as there are low rates of satisfaction among managers in industry about capabilities and skills of fresh engineering graduates from local universities.

It is evident that to produce quality power engineers, stakeholders in the energy sector need to be more aware of renewable engineering practices. At an institutional level, the industry needs to actively collaborate with universities to produce well-developed resources for educators to use. Educators also need to be well informed of the social benefits of incorporating sustainable development in teaching materials and encourage students to apply sustainable thinking to power engineering. Lastly, students' awareness in the field can be enhanced through an integrated package that incorporates the study of technologies, resources, systems design, economics, environmental dimensions, industry structure and policies.

2.2. Industry patterns

The next category of research papers delves into the climate of renewables in the power engineering industry. Employment in this area is rapidly growing with some developing countries having a 10% growth rate to build more power systems [8]. Among all countries, China, Brazil, USA, India and Germany are the top five largest employers for renewable energy resources (RER) and according to Green Peace International, 6.9M jobs will be available in 2030 in the global energy industry [9].

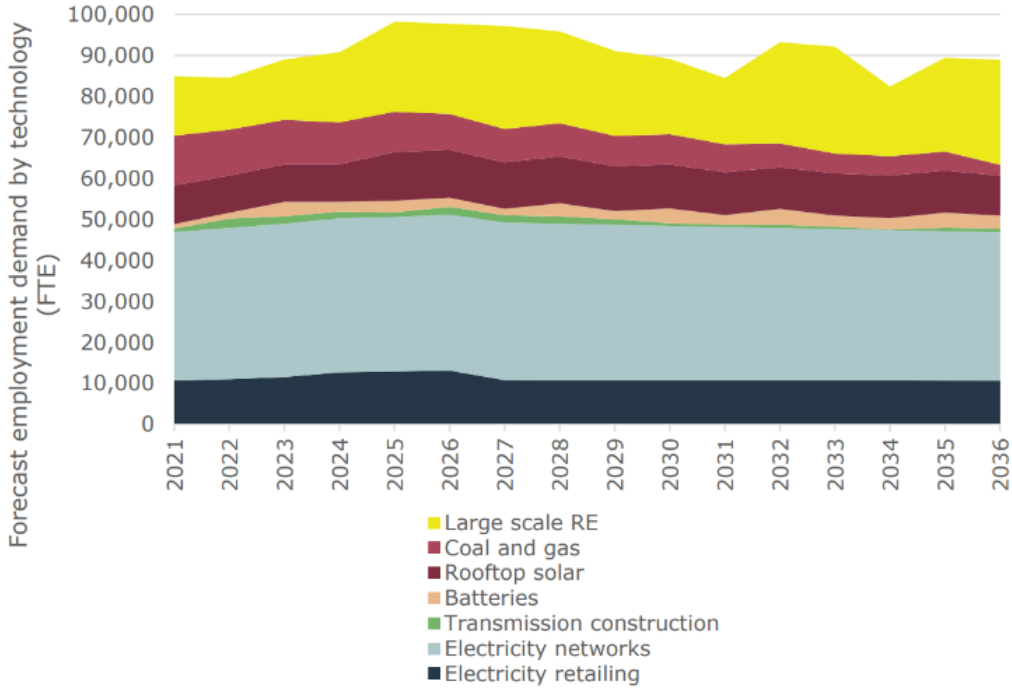

Figure 1. Forecast total labor demand, power sector (by sub-sector, 2021-2036) [10].

As seen in above graph, electricity networks, large scale renewable energy (RE) and rooftop solar are amongst the largest sources of labor demand. It is important to analyze job opportunities within these fields and develop course curricula accordingly. Thus, undertaking an in-depth analysis of the knowledge and skills requirements of each job opportunity in the field of renewable energy is necessary. As a major contribution of this paper, this will be explored further in Section 3 Data Collection – Industry Interviews.

Some of the current problems a country faces when building powers systems using RER are space for energy storage, cost of power generation and insufficient research into new forms of energy resources to build mainstream systems. Resources such as hydro-power and geo-thermal energy are under-utilized but have the potential to provide adequate amounts of electricity for commercial use if combined with more common sources of renewable energy such as solar and wind.

The RE industry has 4 major sectors [9]:

- Manufacture and distribution of RE equipment, including the necessary research and development (R&D),
- Project development,

- Construction and installation work for the development of RE projects, and
- Operation and maintenance (O&M) of RE facilities.

From these sectors, many professions, both technical and non-technical have been established. These include:

- **Technicians:** those who work with tools and special equipment and manufacture products to standard, and often are tradesmen or apprentices.
- **Technical Designers and Consultants**: professionals who spot technical opportunities to design and innovate power systems that improve output and cost effectiveness.
- **Energy Advisors and Experts**: those who advise on national and/or regional policies related to RE planning and operation, as well as on energy management and efficiency.
- **Business Executives:** decision makers who spot new business opportunities, create proposals, negotiate with potential customers and ensure customer's needs are met all along the renewable energy supply chain.

The skills gaps for the non-technical roles are due to poor communication about RE technologies, their social/economic benefits, environmental policies and regulations at international, national or regional level. Specific measures have been launched by governments for assisting projects and other initiatives to counteract this [3][11].

The widespread skills gap amongst technical roles, however, is somehow due to existing programs and education training providing only basic knowledge of how RE technologies operate. This, coupled with a shortage of qualified trainers with specific knowledge of RE technologies makes it hard for the skills gap to be bridged.

In addition to the skills gap, some of the current problems a country faces when building powers systems using RER are space for energy storage, cost of power generation and insufficient research into new forms of energy resources to build mainstream systems. For example, in the case of the booming PV industry, there is a concern for utilities regarding the future business model. Generators may lose a share of the energy market, particularly during the daytime peak load periods where the electricity prices are quite high. Grid constraints such as the lack of capacity or availability may limit the growth of wind energy technologies in some areas that have good wind resources. Integration of wind power systems to the current grid may be needed to accommodate further wind energy development. Geothermal energy is a novel resource and has the potential to contribute to electricity generation. Companies and government initiatives are exploring different ways to incorporate geo-thermal energy more into the industry, however, no commercial energy has been produced [12].

The patterns in the renewable energy industry indicate high employment growth and therefore an increasing need for specialized personnel. As discussed above, Australia requires qualified engineers with the appropriate skills to deal with challenges of economic dispatch, distribution networks, operation of market frameworks, integrating renewables to the electrical grid and their impact. This, again, is to be addressed by the education system.

2.3. Endeavours by the education system

The final category of this literature review summarizes the attempts by the education system to prepare students for the industry. Following from Section 2.2 Industry Patterns, it is necessary to undertake an in-depth analysis of teaching and training programs in the field of renewable energy and compare it to the knowledge and skills requirements of each job opportunity. In 2014, the American Society of Mechanical Engineers stated [13]:

"Engineering graduates do not possess necessary skills to tackle sustainability related problems. Current engineering curricula are not equipping them to properly deal with these

challenges due to little integration of sustainable and green design strategies and practice...These concepts and methods are still relatively new to engineering curriculum and are not an established practice for most of such programs."

This is especially apparent at a university level, where students undertake courses for a more in-depth understanding of the area of study, but in the case of power systems, the content is not diversified enough to accommodate for emerging concepts, such as renewable energy. The breadth and scope of power engineering education are at odds with each other. Often an introductory course covering many renewable resources cannot go into detailed theory in senior level courses (i.e., fourth year and postgraduate level courses), let alone how to operate and maintain technology that use them. The curriculum framework is outdated and needs to be developed in this case. Regular resource assessment is often neglected in a significant number of teaching/training programs. Similarly, adequate treatment of the techno-economics and financing of renewable energy technologies is not included in many of the existing programs.

Many research studies make a point on a skills shortage through relevant firsthand and secondhand data however, few make direct suggestions to change course content. After a review of papers that address this concern [14], the features of a desirable RE program can be concluded as below:

- Cover all renewable energy sources,
- Cover all aspects related to dissemination and development of RE technologies,
- Establish synergy with energy conservation,
- Provide balance between theory and practical aspects,
- Is compatible with global efforts,
- To extent possible, offers employment after successful completion of courses related to RE, and
- Should be taught in local languages for better accessibility of education.

One paper has suggested an example program structure with the above features incorporated [15]. It is one of the few comprehensive program structures designed to combine thorough technical knowledge of RE and relevant industry requirements. The Renewable Energy Engineering Technology program was proposed by Dr. Alireza Kavianpour of DeVry University and offers the following courses:

- REET 100 Alternative Energy Technologies with Lab: introduction to RE technology. Socio-economic, environmental, and regulatory issues will also be considered.
- REET150 Power Electronics and Alternative Energy Applications with Lab: teaches power switching circuits such as rectifiers, AC-DC and DC-DC converters, inverters and motor drives.
- REET200 Electric machines and Power systems with lab: Topics include three-phase circuits, power-factor correction, transformers, synchronous machines, dc motors, induction motors, power-system transmission and distribution, and an introduction to power-flow studies.
- REET 250 Renewable Energy: Science, Technology, and Management: Introduces science of RE technology and business decisions to invest in and manage systems. Solar technologies, fuels synthesized from biomass, hydrogen and wind are explored.
- REET 300 Sustainability Management and Administration: Planning, supportive information systems, compliance management, the sustainable supply chain,

sustainability applied to human resources, and other sustainable system elements managed and controlled by operations are considered.

- REET 350 Sustainability Operations: explores through organisation's commitment to sustainable development at a management and administration level.
- REET 400 Sustainability Marketing: marketing from sustainable practices. Opportunities to develop product pricing, channels, promotion, and markets.

Australian universities offer courses in renewable energy technology, energy efficiency, energy management and energy policy and planning. While many universities offer robust education in photovoltaics, passive solar design, energy efficiency, and solar thermal systems, very few provide research opportunities in energy policy, energy economics, or other renewable energy resources (RER) [16]. Further investigation into what specific power engineering courses is taught by universities will be done in Section 3, Data Collection.

The emerging trends in education show a clear focus on bringing renewables to the forefront of power engineering, although this is still in the early stages of development. As mentioned above, the redesign of program structure and material will be necessary in order to build strong foundational skills in future power engineers.

From this literature review of current academic research, it is evident that a more standardized and developed education is required to bridge the gap between knowledge and skills. While there are numerous papers that delve into power engineering curricula, only a limited number of them conduct comparative studies to evaluate the degree to which these curricula correspond with the needs of the renewable energy industry for technical professionals. Thus, the aim of this paper is to reinforce the research that has been done and specifically propose areas of improvement to course content that accounts for the new skills required to navigate a global energy transition.

3. Data Collection

The data collection involves interviews with industry professionals focusing on specific knowledge and skills required by power engineers to form an understanding of the authentic requirement in the industry. To compare against this, power system related courses and programs at Australian universities are also investigated. This is to determine how appropriately renewable energy concepts are incorporated into the current curriculum. These sets of data are analyzed qualitatively to uncover and highlight the initial gaps between university education and industry required.

3.1. Industry interviews

A series of 10 interviews were conducted with professional engineers working in a variety of power companies to see what should be included in the renewable energy power curriculum from an industry perspective. The professionals chosen for this section of research were required come from a variety of different sectors such as:

- project management,
- academia,
- systems design,
- research and development, and
- energy market consultancy.

As mentioned in Section 2.2 – Industry Patterns, many technicians, project managers, construction workers and analysts will be highly sought after with the expedited growth of the renewable energy industry. Thus, a diverse selection of interviewees was necessary to investigate an equally diverse skillset that should be incorporated into the teaching material. Participants have been active in the industry for 1-10+ years with 80% specializing in energy/power systems engineering as can be seen in Figure 2. The participants were asked 8 questions relating to their expertise, expectations of graduates and their opinions on their educational background as well as some additional follow-up questions as listed in Table I. This approach was taken to obtain a comprehensive understanding of the skills and knowledge that industry professionals deem essential for recent graduates to possess.

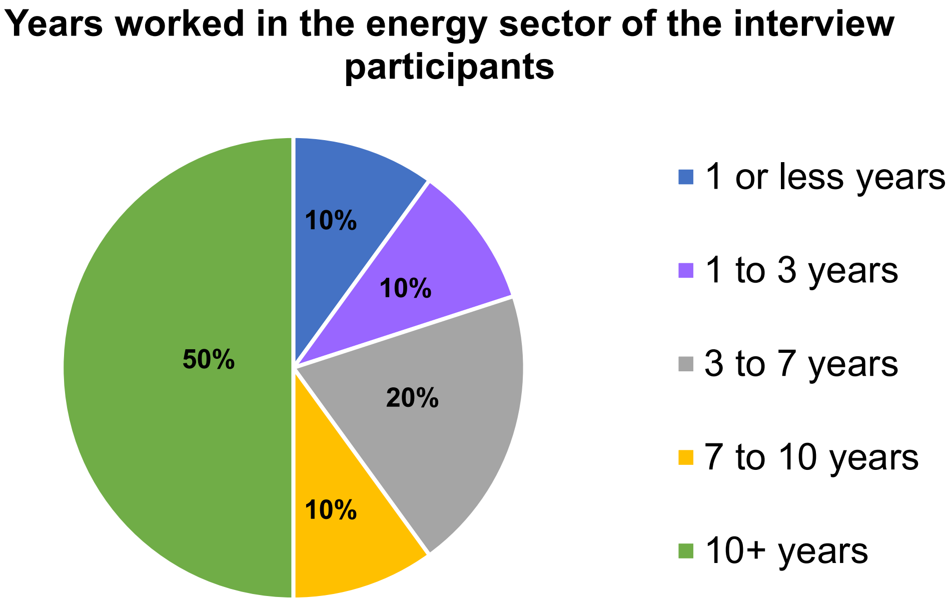

Figure 2. Years worked in the energy sector.

Participants overall agreed that renewable energy education should be prioritized in the power curriculum as the rapid changes in the energy sector calls for updated training and retraining in the workplace. The areas of interest on how course content can improve is divided into 3 sections:

- Modelling and Simulation
- Impact of Renewables on Electricity Distribution and Electricity Market Policy
- Stability and Reliability in designing renewable energy systems.

3.1.1. Modelling and simulation

One area of interest is the ability to accurately model system components, such as power inverters, and energy storage systems as it is a skill that is in high demand. For example, one participant explained they learned power system modelling in a more practical manner through an internship. Modelling through software packages, such as DIgSILENT PowerFactory, PSCAD and PSS/E is common in the modern power industry. During their internship, an engineering consultant recounted the importance of using the industry software to perform simulation studies. It is highly desirable for graduates to have learned modelling techniques -

"... would do the modeling to check how a power system network would operate under certain conditions and check that it actually meets the standards."

Power electronics were a specific technology that had great significance in generation of electricity and are pivotal in converting renewable energy to more useful forms and yet, an

Table I. Interview Questions.

No.	Junior Engineer	Senior Engineer
1	Please introduce yourself and give a brief background into your career.	Please introduce yourself and give a brief background into your career.
2	How do you see your current line of work changing now that the power industry is moving towards a clean energy future?	How do you see your current line of work changing now that the power industry is moving towards a clean energy future?
3	What technical skills were expected of you when entering your current role?	What technical skills do you look for/expect from graduates.
4	What kind of training was provided to you when you started your position?	What kind of training do you provide when graduates start their position.
5	What renewable technologies do you use in your work? What kind of knowledge/technical skills do you require for this job?	What renewable technologies do you use in your work? What kind of knowledge/technical skills do you require for this job?
6	Did you go to university? If so, when did you graduate and how much of what university has taught you directly applies to your job? Explain in detail.	Current power engineering curriculum often involves the following topics/courses - Introduction to circuits - Electrical Energy/electromagnetism - Power Electronics - Power systems equipment, protection, analysis - Energy generation, transmission, distribution Is this list up to date - does it extensively cover the knowledge required by professionals in the power industry?
7	Can you give examples of when your degree/diploma/certificate did not prepare you for the knowledge needed to complete your job?	The information on renewables is vast, diverse and often hard to teach in a couple weeks as a subsidiary part of a course, with enough detail and appreciation. From your learning experience, do you believe renewable energy concepts should be included in current undergraduate courses or have their own individual set of courses dedicated to them in the power curriculum?
8	What other topics would you have wanted to know before entering the power industry?	What topics would you like power engineers to know/better understand before entering the industry?

accurate model for power inverters is rare in industry, let alone taught in university. This is exemplified by a graduate recruitment officer's response below:,

"... we commonly look at capabilities in power electronics because that is an area in the power industry, where traditionally we've had a deficit".

Existing network elements such as mechanical regulators will soon be replaced by fast-switching power electronics devices and their impact on stability must carefully be considered for an efficient model to be built. The use of power electronics was heavily emphasized, and one academic noted:

"You could almost have the whole other program on inverters, because there's such a complex piece of machinery ... Very rarely do I see students who fully understand it".

Another software used in industry is Plexos, a unified energy modelling and forecasting platform which offers long term and short-term market simulations. This can then be used to decide market factors such as pricing of electricity to send to consumers and so modelling/simulation becomes important for understanding the economics of power distribution as well as generation. Despite software handling the more complex calculations for power system analysis, understanding results and conclusions of a computation is highly desirable [11]. For example, energy storage solutions often rely on modelling lithium technologies such as batteries but background knowledge on how lithium batteries work as well as the having a deep understanding of system capacity will be needed to take full advantage of such modelling packages. Thus, it is equally important to pair competent use of simulation software with meaningful theoretical knowledge for students.

3.1.2. Impact of renewables on electricity distribution and electricity market policy

The economy of the power industry is anticipated to drastically transform with the transition to a zero-carbon future. Economic dispatch of electricity will be a topic to develop learning material as pricing designs, regulations and tariff reforms are expected to change once renewables are connected to the grid. When asked how the use of renewables would affect distribution costs, a participant stated,

"With more advanced technology, we can deploy sophisticated tariffs in terms of setting prices not quite in real time, but in 5-minute intervals ... we are applying that to distribution costs to allow us to best use the resources of the future,"

indicating the necessity of understanding how market structure and electricity pricing will inevitably change in order to supply consumers with affordable renewable power.

To accompany this transition, new standards and regulations will be introduced and will impact choice of technology, locations to build infrastructure, how much control a network has etc. Network consumption analysis such as how to import/export power from micro/smart grids, and the effect of stress by external factors such as drought or cloudy weather is another topic worth including as such systems will be very different from coal-powered systems.

The availability of renewable energy resources in select areas will also determine where to build electrical infrastructure and will consequently have an impact on communities and environments alike. Many projects are currently underway for this type of construction, with one project manager saying.

"…we're actively trialing a number of community style micro grids ... and at a more remote level, we are championing standalone power systems, so we're looking at whether a customer can become self-reliant (independent of the grid) without needing to roll out a traditional network solution?"

Another participant mentioned:

"Have a look at the skills associated with decarbonization jobs, there's no course to take to address those skills in Australia. Most of the time, there's probably going to be an engineer who's then been working in the industry for a while that has some experience around energy policies."

indicating how energy policies could possibly be incorporated more into the curriculum if space is permitted. However, this would have to be balanced with other necessary technical concepts.

Other participants working in the project management and consultancy space have expressed that with the energy transition fast approaching, network operations and market policies will have a huge impact on how power will be distributed. It is currently a learning hurdle to be updating procedures and learning new standards as new technology becomes available. The power industry ultimately must cater to their customers and provide fast effective solutions with every update of information and therefore, understanding the economic changes/processes from moving towards clean energy will be valuable to learn during university.

3.1.3. Stability and reliability in designing renewable energy systems

Inevitably, problems with power systems protection, equipment and analysis will all require different approaches to solve. Some participants highlighted that, *"A lot of the calculations and the philosophies are not really designed for these microgrids or these sorts of smaller supplies."*

"Power systems protection ..., assumes a rather old school power system, one without inverters and lots of harmonics to it. We don't teach it very well at university because things change so quickly".

referring to how traditional methods of analysis are not accurate when considering RER generators that are unstable compared to their coal-fired counter parts.

Protection of power equipment often involves understanding fault currents, which can trip protection devices and isolate parts of a system, and where they originate from. A large source supply will result in a large fault current, but smaller supplies such as from solar panels or wind turbines do not provide a large amount of power. And so, a fault in a 3-phase system can go unnoticed or be very hard to discriminate with other signals. Thus, calculations must now assume a smaller fault clearance than what they are used to and protection devices must be redesigned to handle this new constraint in order to maintain the reliability of the system. Ultimately, it is clear that students should at least,

"...understand the nature of a power system and why you would have different voltages".

Other challenges present themselves in the islanding of source supplies, where renewable energy supplies can disconnect from the grid when met with abnormalities or sub-optimal conditions. This is inherently due to renewables lacking inertia to keep the grid in a state of stability in the event of a voltage collapse for example. So current protection schemes become redundant and therefore is a gap in technical knowledge that should be addressed. Design and planning teams in generation, transmission and distribution companies are currently facing issues to build a stable and reliable network that will support an industry soon to rely 100% on renewables.

3.2. Curriculum Investigation

After collating the responses from industry professionals which emphasized the essential skills and knowledge for graduate power engineers entering the renewable energy space, it became apparent that that a review of the current curriculum was needed. The responses can then be compared against power subjects in order to see what areas can be improved to meet industry demand. 43 Australian university course curricula were researched to see the diversity of power engineering subjects taught. The universities selected (31) for further investigation:

- Offer electrical engineering as an undergraduate degree/diploma.
- Offer at least one power engineering subject.

A total of 208 power engineering subjects are offered in the current curriculum. These include all undergraduate energy related core and elective courses. As outlined in Table II, New South Wales, Victoria and Queensland are the states with the highest number of universities that teach power engineering courses, possible since they have the largest populations. A compilation of the course descriptions, learning outcomes, prerequisites and assessment structure of all 208 subjects has allowed for a deeper analysis on the robustness of energy programs in Australia. Queensland and Western Australia offers the most power-related subjects, averaging about 9-10 per university compared to the national average of 6-7 and consequently has the highest number of subjects that specifically cover renewable energy concepts and technologies. These will be looked at more closely than others. From this comparison the typical structure of power engineering degrees is as follows:

  - Introduction to circuits
  - Electromagnetism
  - Electrical energy/machines

- Electronics
- Power electronics
- Energy generation/transmission/distribution
- Power systems equipment, protection, analysis

Some new subjects incorporating emerging concepts and techniques include:

- Electrical Machines and Renewable Generators
- Renewable Energy Integration into the Modern Power Grid
- Principles of Renewable Energy Sources
- Electricity Market and Power System Operation
- Biofuels, Biomass and Wastes
- Renewable Power Technologies
- Grid Integration of Renewable and Storage Technologies

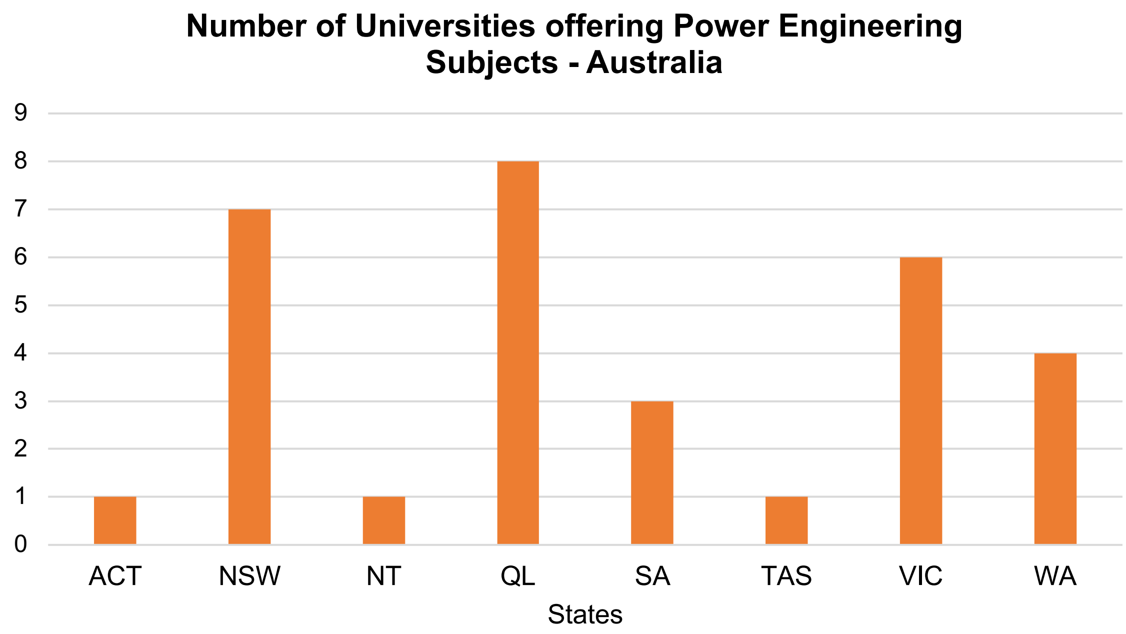

Figure 3. Number of universities offering power engineering subjects – Australia.

Table II. List of Australian universities offering power courses by state.

State	Universities offering Power Engineering Subjects
New South Wales	University of New South Wales University of Sydney University of Western Sydney Macquarie University University of Technology Sydney University of Newcastle University of Wollongong
Australian Capital Territory	Australian National University
Victoria	Deakin University Monash University The Royal Melbourne Institute of Technology Swinburne University University of Melbourne Victoria University

State	Universities offering Power Engineering Subjects
South Australia	Flinders University Adelaide University University of South Australia
Western Australia	Curtin University Edith Cowan University Murdoch University University of Western Australia
Northern Territory	Charles Darwin University
Queensland	Central Queensland University Federation University of Australia Griffith University James Cook University Queensland University of Technology University of Queensland University of Southern Queensland University of the Sunshine Coast
Tasmania	University of Tasmania

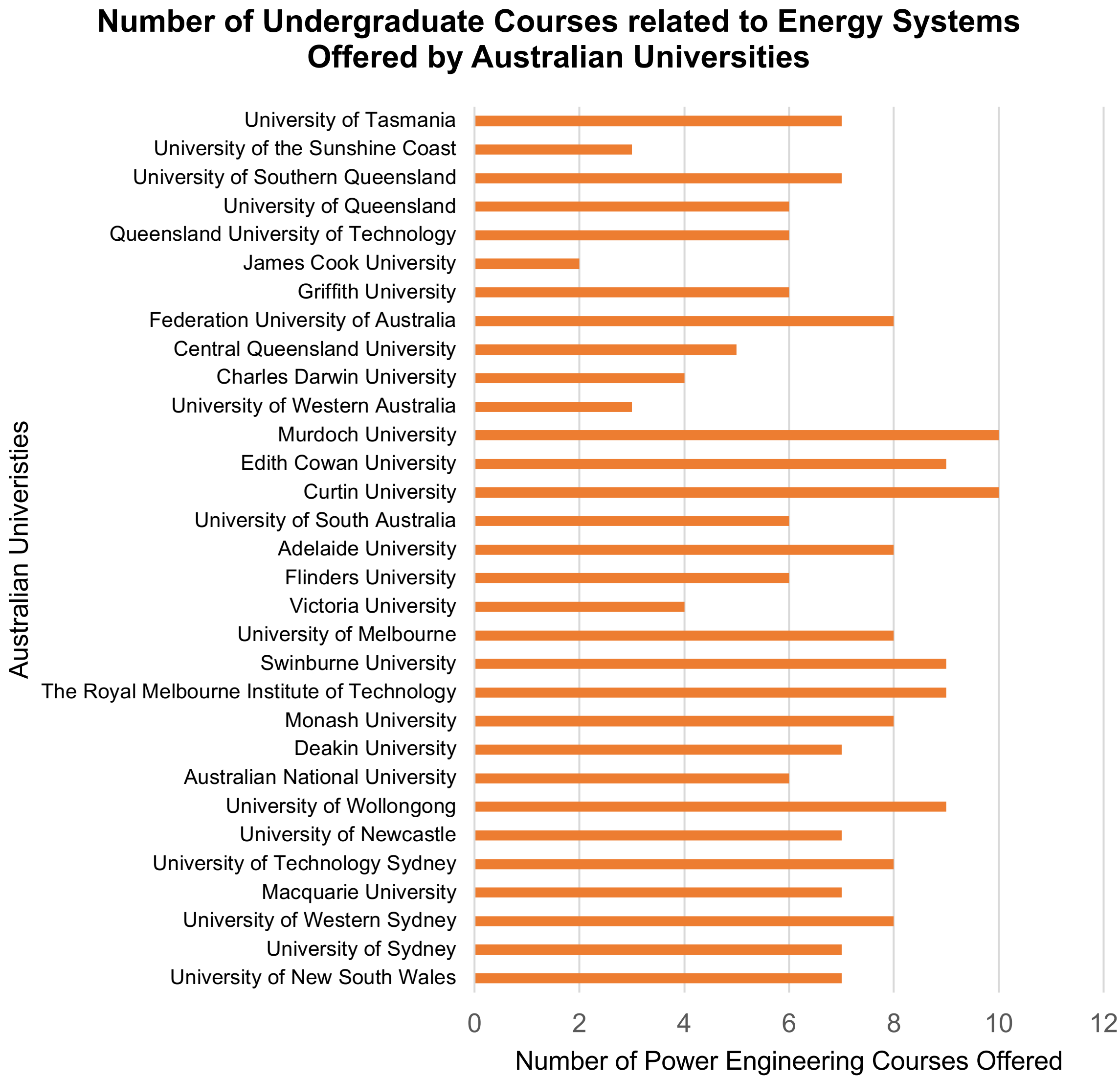

Figure 4. Number of undergraduate courses related to energy systems offered by Australian universities.

Course descriptions have varied from giving a general overview of the subject to a detailed list of topics that will be taught during the semester and have highlighted strengths and weaknesses in the incorporation of renewable energy related content. Examples of the level of detail some subjects have towards renewables is shown below:

Some core strengths of power subjects include explaining characteristics of solar and wind powered systems, understanding the operation of modern electricity grids and the impact renewable energy sources have on it and identifying renewable electricity usage in the residential, commercial, and industrial sector. While this is commendable, very few subjects address the hydro-power technologies which can stabilize renewable generation compared to unreliable sources such as solar or wind. Traditional analysis of power systems is not accompanied by emerging trends such as how power inverters, which do not offer the same stability as synchronous generators, convert energy from renewable resources and analysis of faults that can ensue in such systems.

In addition to the course description, learning outcomes have listed key skills that will be acquired by the end of the teaching period for a subject. They consistently promote the importance of good teamwork, excellent communication skills and a high aptitude for learning independently, which are key targets for all graduate engineers. In terms of technical skills, there is emphasis on the following target areas:

- Identifying components of power systems and the resources used to create electricity.
- Critically analysing, designing, implementing, and evaluating power systems using appropriate tools and analyse transmission systems for their efficiency.
- Explaining operation and principles of electric machines such as motors, generators, and transformers
- Applying theory and principles taught in practical settings.
- Understanding challenges and solutions of the large-scale renewable energy integration to the distribution and transmission systems.
- Performing power system calculations involving power and energy requirements, voltage drops, power factor correction and fault currents.

Assessment generally follows the format of assignments, mid-semester exams and final exams. As research has shown, assessing students' learning through traditional 'sit-down' exams does not always test how well they understand content. These types of assessments also limit the ability to test the target areas mentioned above. Some universities have structured their courses on project-based learning such as UTS and Deakin University which assess students through a combination of project proposals, prototype design/presentation and final reports/portfolios, allowing them to test how well students model and analyze major types of components including renewable generators in modern power systems.

Overall, the course outlines investigated show a very strong background in analysis of traditional power systems and stress the importance of understanding their operation and performance. There has been some attempt to incorporate emerging renewable energy technologies and systems, with some universities performing stronger on this area than others. However, it is suggested that power engineering curricula needs to include a number of different factors, detailed in Section 4, in all universities to be fully capable of achieving Australia's energy targets.

4. Gap analysis – Industry Demand vs Current Curriculum

The curriculum investigation and industry interviews have demonstrated various gaps of knowledge within the current power curriculum. From the primary and secondary data collected, 4 key factors that are not sufficiently addressed in the power engineering content taught at a university level:

- **Modelling renewable energy power systems and technology and performing system level studies using industry software packages:** Now that new technology is available to simulate complex high voltage structures, hand calculations have become tedious for analysis. It is much more valuable that engineers are able to use and interpret data from simulation/modelling software which will handle most heavy calculations in industry.
- **Understanding electricity/power market structure and policy:** University power subjects have a strong focus on traditional technical knowledge such as calculating the power consumption of a transformer or analyzing short circuit faults but rarely touch on the economic aspects of the energy sector. As seen in Section 3 Industry Interviews, the electricity market structure/policies are just as important to know as technical concepts since the power industry is heavily customer focused. Understanding the needs of consumers, where to build substations, how to deliver electricity to them, the environmental impacts in doing so and how to appropriately price electricity are all worthy of study as an undergraduate.
- **Designing and understanding renewable energy dominated - systems which use biomass, hydro and geothermal sources based upon their characteristics:** The focus on solar and wind as renewable energy sources must shift to encompass the wide variety of others available in Australia. A wide variety of technologies have been developed to harness the power of such sources and should be brought to attention in the curriculum if they are to be gradually utilized in the Australian climate. Doing so can potentially pave the way to meet high energy demands of the country, where millions of people are depending on a secure reliable supply of power.
- **Designing microgrids and smart grids either physically (hardware) or virtually (simulation) to meet specified criteria and performance standards:** Microgrids and smart grids are becoming increasingly popular in industry and are a common infrastructure in many power companies. The stability and reliability of such grids are a current concern and engineers that can improve their operation and performance are in demand. Analysis of such systems also requires review of standards/specifications which are under constant revision as the energy sector faces massive changes. These standards should also be included in the curriculum alongside the technology they mandate.

To address these deficits, a number of improvements are suggested. Table III summarizes the main concerns from interview participants and compares them to current subject matter.

Table III. Comparison between power industry requirements and course content.

Industry Interview	Current Curriculum	Suggested Improvement
Build intuitive understanding of simulations and highly adept at modelling renewable energy technologies/systems through software.	Analyse and predict performance of various renewable energy technologies such as smart grids/microgrids.	Incorporate use of PSS/E, PSCAD, RSCAD, DIgSILENT PowerFactory and PLEXOS in appropriate elective courses. Have a deeper focus on power electronic on the grid, possibly create a stand-alone subject for this.
Understand different methods of renewable power generation other than solar and wind.	Describe characteristics of solar and wind-powered systems, evaluate their functionality, benefits and disadvantages.	Include theory surrounding hydro-power and geothermal systems in introductory energy courses. Review/design/analyse such systems in more advanced courses.

Industry Interview	Current Curriculum	Suggested Improvement
Consistently practice and retain fundamental power engineering skills such as mathematical analysis of fault currents/voltages, energy conversions, coding languages, operation/characteristics/principles of standard machines/systems etc.	Perform power system calculations involving power and energy requirements, voltage drops, power factor correction and fault currents.	Redesign labs/assessments for a more industrialised setting such as workshops to build islanding/anti-islanding systems. Update theory on power protection calculations to accommodate for non-traditional methods of power generation.
Keep up to date with electricity market structure, regulations, interpret relevant standards and understand decarbonization policies.	Understanding challenges and solutions of the large-scale renewable energy integration to the distribution and transmission systems	Use project-based learning to design activities/assignments that requires reference to standards and procedures targeting the economy of the renewable energy industry.
Have an appreciation for evolution of electrical infrastructure such as redesigning of substations, network control systems, new low voltage and high voltage technology etc.	Apply theory and principles taught in practical settings such as lab environments.	Organise site visits to sub-stations to consolidate learning and include guest speakers in lectures/tutorials to clarify practical application of subject matter.

5. Conclusion

This paper has conducted a comparative study of the responses of professional power engineers and the curriculum framework in power engineering. The research analyses and identifies the knowledge and skills gap between teaching content and industry demands and has recommended improvements for the power engineering curriculum.

To further support the development of highly qualified power engineers, future work involves another key aspect – students' perception in the field of power systems and how much they understand current industry knowledge and practices. Students with a power system background at different levels of a program can be recruited for additional qualitative data collection. Focus groups can be conducted to reveal areas of the curriculum that require improvement from the students' point of view and can reinforce the suggestions made in this paper. The extended study can guide educators to design more industry-oriented and student-centred power engineering courses that provide students with a strong technical foundation, preparing them to confidently pursue careers in renewable energy.

Overall, this paper provides valuable insights into the current state of power engineering education in Australia and highlights the need for ongoing efforts to integrate renewable energy topics and technologies into the curriculum.

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