A Course in Power System Analysis based on Project Based Learning Methodology

N. Hosseinzadeh, Member IEEE, and M. R. Hesamzadeh, Graduate Student Member IEEE

Abstract- A growing need in the electrical power industry for engineers who can perform professionally both in technical aspects and generic engineering skills has put a demand on universities to modify their programs and course structures. To address this demand, a course in power system analysis which used project based learning (PBL) methodology was developed. As a part of this development a power system laboratory was established, which gave students access to professional software packages. Projects were defined in the areas of power system operation and planning. These projects were used as stimuli for student learning. Portfolio assessment was used to assess students learning outcome. The course was delivered for the first time in 2008. The feedback from students was very positive and promising.

Keywords: Project Based Learning (PBL); Engineering Education; Power System Analysis; Portfolio Assessment in PBL

I. INTRODUCTION

For about two decades, universities and industries experienced a period of low interest from young generations towards undergraduate engineering programs in general and electrical power engineering in particular. For example, the percentage of undergraduate electrical engineering (EE) students committed to electric power in the USA declined from 1978 to 2001. In the 1970s, power engineering represented between 10 and 15% of the undergraduate EE enrolments; in 1992 it was 7%, and its minimum occurred in 2001 at about 5.9%. It seems that students have shown more interest in the power engineering area in the USA since 2001. The 2002 data showed that the trend was reversed back to approximately 7% [1].

In Australia, a period of downsizing power industries from 1997 meant that less graduates were required and the funding for higher education and research in power engineering declined substantially. This resulted in an inevitable, significant and continuing decline in the ability of Australian universities to carry out teaching and research in power engineering. As the trend in power industries changed from about 2003, the demand for power engineers increased. Gradually, a shortage of power engineers was noticed by the industry leaders. Consequently, the power engineering industries started to seriously support the universities to promote power engineering programs. Australian Power Institute (API) was established on a national scale [2]. API is a not-for-profit national organization established by the electricity power industry to boost the quality and numbers of power engineering graduates with the skills and motivation for a career in the energy industry. The key objectives of API are to achieve the following [2]:

• Attract students to consider power engineering as an exciting whole-of-life career choice.
• Facilitate world class undergraduate power engineering courses and academic resources available to students.
• Provide value adding post graduate development and applied research to industry.
• Position API as a vibrant, well respected organization by key stakeholders, i.e. industry, universities and government.

In the State of Queensland, a Power Engineering Alliance (PEA) was established in 2005, which comprised from leading industries and universities in Queensland. PEA amalgamated with Central Queensland University (CQU) from 2005 to 2008. The interaction of PEA with Central Queensland University (CQU) from 2005 to 2008 made it possible to establish a modern laboratory for conducting a course in power system analysis based on project based learning (PBL) methodology. Professional software packages were made available to students to conduct real-world projects, which they would encounter after their graduation in the relevant industries.

The PBL unit of study Power System Analysis was developed and offered as a part of the Bachelor of Engineering co-operative/ Diploma of Professional Practice (BE/Co-op) [3]. The program philosophically relies on PBL methodology in facilitating student learning [4].

As a part of a major review of undergraduate engineering programs in 2006, the Electrical Engineering Discipline Group was delegated the task of devising the program content for its discipline plans. The outcomes of this review for the electrical discipline were new plans for undergraduate electrical engineering programs with more emphasis on using PBL in teaching courses in electrical power engineering [5].

This paper discusses the development and delivery of a new PBL study unit Power System Analysis as an example of the layout of individual subject units within an integrated PBL program. In order to develop the course to facilitate student learning tailored to the industry needs, strong linkage was formed through collaborative research projects and ongoing networks to ensure student learning was industry relevant and real-world focused. This included:

• ensuring course content was relevant and up-to-date
• developing and implementing pedagogies that focus on active learning and problem solving
• collaboration with industry to ensure undergraduate projects had a real-world basis and application
• development of cutting-edge learning facilities and resources that were congruent with industry conditions.

By making classroom learning experience industry-relevant, interactive and student-centred, educators were able to influence, motivate and inspire student learning. The assessment of the course was done using a number of proven techniques in assessing PBL courses including portfolio assessment and performance-based assessment [6].

II. PRE-REQUISITES OF THE COURSE

As pointed out by [7], the knowledge and experience learned by the students in their earlier stages of studies play a major role in the success of PBL. Prior to the PBL unit of study Power System Analysis, as a part of the BE(Co-op) program associated with the Diploma of Professional Practice at CQU, students are required to do the following units of studies. Note that the subjects with 12 units-of-credits (uc) are run completely in PBL, but the 6 uc subjects are delivered in a hybrid mode, i.e. lectures and problem-based-learning methods.

Engineering Skills 1 and Engineering Skills 2 (each 12 uc)
Engineering Foundation Mathematics (6 uc)
Engineering Mathematics (6 uc)
Engineering Physics A and B (each 6 uc)
Materials and Processes (12 uc)
Engineering Design (12 uc)
Engineering Mathematical Applications (6 uc)
Engineering Project Management (6 uc)
Electrical Circuit Analysis (6 uc)
Electrical Power Engineering (6 uc)
Professional Practice Preparation 1 (6 uc)
Industry Placement 1 (12uc)

By doing these subjects students have a fair technical background and also a complete understanding of how PBL units of study are done before entering the Power System Analysis subject. The introductory subject Electrical Power Engineering is offered in the second year and builds up the fundamentals of power engineering. The prerequisite for this course is Electrical Circuit Analysis.

Among the generic skills that students have gained in the previous PBL subjects are their
• ability to communicate effectively
• ability to undertake problem identification, formulation and solution
• ability to utilise a system approach to design and operational performance

A PBL unit of study is expected to have the following characteristics [8]
• Reliance on problems to drive the curriculum - The problems/projects do not test skills; they assist in the development of the skills themselves. Problems are similar to the ones encountered in real world.
• The problems are ill-structured - There is not meant to be one solution, and as new information is gathered, perception of the problem, and thus the solution, changes.
• Students solve the problems - Teachers are the coaches and facilitators.
• Students are only given guidelines for how to approach problems - There is no one formula for student approaches to the problem.
• Authentic, performance based assessment is used.

III. DEVELOPMENT OF THE PBL STUDY UNIT

Power System Analysis is normally offered in the third year of the program. This study unit is expected to cover the main concepts in operation and planning of power systems. The development of this new PBL study unit involved the creation of a Power System Laboratory. Although similar laboratories can be found in many other universities across the globe, the way that it has been used to conduct PBL methodology in facilitating deep learning of students based on real world problems makes it different and perhaps unique at this stage of time. In this subject, projects have been defined in the following areas.

• Modelling of power system components
• Load flow studies
• Fault studies
• Economic dispatch
• Load forecasting
• Power system planning
• Power system stability

Professional software packages, which are used by Australian transmission and distribution companies, such as PSS/E, PSS/SINCAL and PSCAD have been made available for students to conduct the above projects. This gives students the opportunity not only to learn the learning outcomes as per a Course Profile designed for this course, but also to learn software packages that they will use in the relevant industries after their graduation. Students’ prior background, knowledge and experiences enable them to undertake the defined projects and further acquire more advanced topics in power system analysis.

The course delivery includes lectures and workshops. During the lectures, the basic knowledge is delivered to the students. Lectures basically guide the students to learn the required background knowledge more efficiently. On the other hand, during the workshops students learn the professional software packages, conduct the projects, obtain relevant information and learn various facets of the course by doing real-world practical projects. Students are asked to
make teams and collaborate with their team members in doing the projects. The following assessment components are required from the students, who will put all these components together to build their portfolios.

- Project reports
- Reflective journal
- Workbook
- Mid-semester test
- Reflective paper
- Self-grade nomination
- Peer assessment

The ‘project report’ outlines the steps taken in doing each project and the results obtained. Students learn how to write technical reports by doing this. The ‘reflective journal’ includes weekly reflection on issues arising from the conduct of projects as well as reflection on what the student has set out to learn, how they have approached their learning, what they have achieved and what they would do differently in future to improve their learning. ‘Workbook’ contains the intermediate work done by students in performing projects, notes on lectures, tutorials which are done voluntarily by students, etc. ‘Mid-semester test’ is given to students to evaluate basic knowledge that students need to learn in this course and has normally been covered in lectures. ‘Reflective paper’ is written by students at the end of the term, in which students reflect on how they have achieved all learning outcomes of the course according to the course profile. Students must also nominate a grade for themselves and justify it. They should evaluate their peers (team-mates) as well.

The portfolio, which includes all the above components, will then be assessed by the facilitators (i.e. lecturer or instructor). It has been observed that the above components are sufficient to have an effective assessment.

IV. DEFINITION OF PROJECTS

The definition of the projects was based on some industrial work experiences which were carried out by the authors. These experiences combined with the many years of teaching power system courses in different universities may be mentioned as the fundamental background for designing the projects. Initially, the power system projects were classified as:

- Project 1) power system modelling
- Project 2) power system analysis
- Project 3) forecasting in power systems
- Project 4) design and planning in power systems.

In addressing power system modelling, three sub-projects were designed: sub-project 1 on modelling of generation level of a typical power system, sub-project 2 engaging with transmission level, and sub-project 3 modelling of high voltage transmission networks.

By doing these sub-projects, students learn how to model the main components of a power system from generation through transmission to the loads. In parallel to the workshops on the projects, lectures are delivered to give the students the fundamental knowledge on these topics. As students are challenged by the projects, they are normally motivated to learn more about what they have encountered in the projects during the lectures.

In addressing power system analysis, four sub-projects were defined. In sub-project 1 the students were engaged with the concepts of economic operation of the power system through finding the economic dispatch of the transmission system, which was modelled in project 1. The Queensland transmission system was used as a case study.

In sub-project 2, the students were asked to report on the following.

- Determine the Transmission Network Service Provider in the State and explain its responsibilities
- Determine the electricity networks supplying the local area, i.e. the city where CQU is a part of, and its single line diagram
- Type of the electrical conductors which are used for transferring electricity and their technical specifications
- Type of the transmission towers used with their technical specifications
- Derive π and T models of specified transmission lines in the network with their thermal capacities
- Technical specifications of transformers at a specified substation and derivation of their circuit models
- Given a typical load profile, e.g. a peak demand daily curve for the local city, derive the load model (e.g. P-Q constant model) based on typical power factors

In sub-project 3, students were asked to do the following.

- Each team selects one sub-area in the State and draws the single line diagram of the relevant transmission network (It is suggested that students use a suitable drawing software like Auto-CAD for drawing the single line transmission network)
- Students then complete tables related to the Branch Data, Generator Data and Load Data of their selected transmission network.

In sub-project 4, the students were asked to do the following:

- List all existing generators with their minimum generation levels, maximum generation levels, and their incremental fuel costs.
• Find the summer peak and winter peak of the load on the transmission system.
• Find the economic dispatch of the load among generators.

By doing these, students got familiar with the concepts of the marginal cost of a generator, electricity price, and congestion revenue by finding these concepts for their selected transmission system. Students became very excited when they were comparing their calculated results with what were available on the electricity market operator’s website.

In sub-project 2, power flow studies as one of the building blocks of any course in power system analysis was explored from two perspectives. Firstly, after explaining the theoretical background of the concept during lectures, students were asked to write their own code for numerical solution of the IEEE 14-bus case study using the Gauss-Seidel method. Understanding the methodology in a systematic way for implementing it by a computer along with learning a computer programming language helped students not only have a comprehensive understanding of the method, but also become familiar with the simulation studies of a power system.

Secondly, students were asked to perform the power flow study for a meshed transmission network using PSS/E. Then, they did a power flow study for a radial distribution network. By doing these, students learned that although the software does the power flow study for them, but they need to put in many component parameters and network data. They learned about the meaning and significance of these parameters and input data. They also explored the difference between a transmission network and a distribution network. The students were also asked to repeat the power flow study for some specific contingencies and report on the robustness of the system.

In sub-project 3, the fault problem was explored as the second building block of power system analysis. Students were introduced to three different approaches for fault studies. Firstly, they applied the analytical approaches to a simple radial network for finding the short circuit currents. Secondly, they modelled a typical industrial system using the PSS/E software. The system given in [9] was used as the case study and the students were asked to do the following.

• Find the ANSI, IEEE, VDE, IEC, and AS standards which are related to the short-circuit studies.
• Model the example system using one of the available softwares. Report the steady state condition of the system including the voltage and line active and reactive powers.
• Find the weak points of the system in case of three-phase fault at a specific bus of the example system.
• Considering the four major short circuits, which one can cause the worst condition in terms of line overloading if they occur at a specific bus.
• Using the related AS standard for short-circuit study, find the fault currents at the specific locations for a particular fault.

The modelling of a typical industrial system and applying the major faults gave the students an exciting experience on the effects of faults in a power system. Accompanying this part of the project with some video recorded events from real short circuits had very positive feedbacks from students.

Sub-project 4 was designed to accommodate the interests of sharp students. As such, the voltage stability problem in a power system was given to the students as an optional project. Case studies from references [10], [11] and [12] were used to define a project, which involved the students in analysing the system with regard to its voltage stability when various outages occur in the system.

Project 3 introduced the students to the load forecasting concepts in power systems. During the lectures, variable nature of the power system load, unavailability of the power system components, and other sources of uncertainties were explained. As a project on this topic, students were asked to forecast the State transmission system load for the periods of 2 years and 10 years in the future. Interestingly, it was observed that almost all students had gained a good understanding of the fundamentals of a research project. Almost all of them started with exploring different sources to list all available methodologies in load forecasting. Then, they found the positive points and negative points of each methodology and ranked them based on these points. Finally, they chose their best method of load forecasting for the State of Queensland. Having become familiar with some programming languages form the load flow project, each group started coding their own. Almost all of them concluded their works with some validation and justification of their results by comparing their model design variables with the available public information. Three fundamental aspects of a research, i.e. having a good background of the topic, extracting the shortcomings of previous works, and their own contributions to the work could be clearly seen in most of the project reports submitted by students.

In project 4, the final topic in power system studies were explored by defining a project on the design and expansion of the future transmission system. Generation planning and transmission network planning were formulated as optimisation problems. By doing this project, students also had a chance to review what they had learned and this gave them an opportunity to cover their weak points in the previous projects.

V. ASSESSMENT

The assessment of students’ performance in a PBL subject such as the one introduced by this paper demands a careful consideration of various techniques for assessing the students.

“Assessment is a complex field, and almost everybody has an opinion as to what should be done. In recent years, ideas such as authentic assessment, performance-based assessment, and portfolio assessment have received a lot of attention.” [13]
“Two of the defining characteristics of a PBL study unit are that both the content and the assessment be authentic. Authentic assessment is substantially different than traditional assessment that is based on objective and short answer questions. As students are responsible for their own learning in PBL setting, students learn self-reflection where they become proficient in assessing their own progression in learning and also peer-assessment on how to effectively provide constructive feedback to their peers.” [6]

“Authentic assessments are generally categorized into Performance Assessment, Portfolio Assessment, Reflection and Self-Assessment. Performance Assessments test students’ ability to apply acquired knowledge and skills in a variety of authentic contexts and work collaboratively to solve complex problems. Portfolio Assessment involves developing a portfolio that documents learning over time. Reflection and Self-Assessment requires students reflect and evaluate their own participation, learning progress, and products which are essential components of autonomous learning.” [6]

The assessment of students in this subject was done based on performance assessment, a midterm exam and a learning portfolio. The main elements of the assessment were as follows.

1. Reflective Journal for each project, in which students reflected on the way that they conducted each project. The Reflective Journal was developed during the course of each project.
2. Project report for each project. This was expected to be a technical report similar to a project report done by engineers in industries.
3. Midterm Examination, which tested students on their understanding of the fundamental knowledge given to them during lectures.
4. Work Book, which included all the related work that students had done during the course.
5. Reflective Paper, which was submitted at the end of the term and contained the students reflections on how they had achieved the learning outcomes of this subject.

In each step, the course facilitators interacted with the students to check their improvement in technical knowledge, time management, project management and technical writing. Through this interaction, the students performances were assessed. Reflective journals were used for a dynamic evaluation of the students progress, correcting the weak points and enriching the strong points of the lectures and laboratory sessions. Students were carefully monitored during the laboratory sessions for checking their improvement and guiding them to the right way.

In the assessment process, each of the aforementioned five elements was assigned a weighing factor. Each student was evaluated for a grade of Fail, Pass, Credit, Distinction, or High Distinction. The face-to-face interactions of authors with the students were useful for the final evaluation of each student in each team.

Based on the weighting factor of each portfolio component and the grading of each student in each task, each student was nominated a grade. Then, the nominated grade of each student by the facilitators (the authors of this paper) was compared with their assessment of themselves (self grade nomination) and their team member assessment (peer grade nomination, i.e. peer evaluation and feedback).

The results of grade nominations by the facilitators and self grade nominations and peer grade nominations were matched for the 80% of the students. It was observed that 15% of the students could not assess themselves correctly. Checking the history of these students in terms of being present in lectures and laboratory sessions revealed that they had not attended these sessions regularly. This factor definitely contributed to their inability to have a good assessment of themselves. For about 5% of the students the instructors assessment was adjusted based on the student assessment of themselves, their justification of their self nominated grade and their peer feedback.

The final assessment results were distributed evenly. Among 19 students, there were four high distinctions, four distinctions, five credits, five passes and one fail.

VI. FEEDBACK FROM STUDENTS

The course Power System Analysis in PBL was delivered for the first time in semester 2, 2008. The feedback from students was very positive. For example, one of the students summarised his experience in learning power system analysis in PBL as follows.

“I have extended my knowledge of power systems and will leave the course as a much more competent and knowledgeable electrical engineer. I was also able to achieve the goals that I set out to achieve at the start of my course. This included getting a better understanding of electrical power systems and obtaining a ‘feel’ for power system operation and behaviour, as seen in my reflective journal. I also have decided that I would be highly interested in a career in power systems and will be looking to gain employment in this area of electrical engineering.”

Another student wrote:

“... All the questions posed real life problems, which has given me a hands-on experience that is valuable. When I start a job, I will already be on the front foot with the right mindset and approach. An aspect of the course I personally liked is that I could apply academic concepts to industry applications and vice versa. I believe to be a competent power engineer you need both experiences. I’ve attained a basis of knowledge and I am now sufficiently competent to make design decisions in the power industry.”

Also, the following feedback was provided by other students.

“The projects allowed team members to demonstrate professional engineering practice in solving several problems applicable to real life power studies. This work has seen us both individually and as a team achieve technical learning
outcomes, refine team work principles and increase our capacity to function as competent, confident professional engineers.”

“I have enjoyed my time with power system analysis this term, far more than I did with electrical power engineering last year. To be honest, I entered this subject quite worried about how I was going to perform based on my previous experience with electrical power engineering, however I ended up enjoying myself and learning more than I imagined I would. Overall the subject was an excellent learning experience and I particularly liked the implementation of project based learning, rather than a purely theoretical subject.”

“… I believe I have a far more comprehensive knowledge of the principles. At the outset, I had a fairly simplistic perception of basic electrical equipment including cables, generators and transformers. Now I can design to specifications, interpret nameplates and set ratings based upon standards. What I liked in the course is that there wasn’t a single right answer. In design, I must simply be able to justify my decisions.”

“Given a network model, I can determine its state, weak points, robustness and behaviour. After unpredictable results, I understand the limitations of models. The simulation is only as accurate as the input data. I am unlikely to make the same mistakes in the future. I appreciated the opportunity to model faults as this is one of the most important and least predictable aspects of power systems. I understand the serious risk of faults and the need to provide adequate protection.”

VII. CONCLUSIONS

A unit of study in power system analysis using the project-based learning (PBL) methodology was developed and offered for the first time in the second semester of 2008. A power system laboratory was established, which gave students access to professional software packages in power system analysis such as PSS/E, PSS/SINCAL and PSCAD. Projects in the areas of power system operation and planning were defined. These projects were used as stimuli for students learning. It was observed that students learning were optimised when this course was offered as a part of a program which is entirely based on the PBL philosophy. Portfolio and performance-based assessment were used to assess students. The final assessment results were distributed evenly. The feedback from the students about their learning experience was very positive and encouraging.

REFERENCES


Nasser Hosseinazadeh (IEEE-M’86) is with Swinburne University of Technology, Melbourne, Australia. Earlier, he had worked as a senior lecturer at Central Queensland University, as a lecturer at Monash University Malaysia and as an assistant professor at Shiraz University. He graduated from Shiraz University, Iran, in 1986 with a B.Sc. degree in electrical and electronics engineering. He worked in a research centre for five years before starting his postgraduate studies. He received a M.Sc. degree from Iran University of Science and Technology in 1992 and a Ph.D. degree from Victoria University in Australia in 1998. His special fields of interest include power system analysis and planning, power system stability, application of intelligent systems in engineering, power distribution networks and engineering education.

Mohammad R. Hesamzadeh is a member of Engineers Australia, a member of IEEE and also is on the Australian Panel APC1 System Development and Economics of CIGRE.

Mohammad R. Hesamzadeh (IEEE-GSM’08) is a PhD student with Swinburne University of Technology, Melbourne, Australia. His special fields of interest include high voltage transmission system planning and design, electricity market analysis, intelligent system applications in power systems, distribution and rural system studies, and high voltage engineering. He is Vice Chair of IEEE, Queensland Power and Energy Chapter, and a Professional Engineer in Australia.