World Transactions on Engineering and Technology Education
Vol.12, No.4, 2014

Development of a modern power systems laboratory

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ABSTRACT: Engineering community unanimously agrees that practical experience in engineering educational laboratories is of fundamental importance and should be a compulsory part of all engineering programmes. However, many universities lack resources to replace or upgrade the ageing and out-dated laboratories, such as electrical power laboratories, where cost of the equipment is high and number of students is low. In most such cases, students' practical experience becomes limited to computer simulation laboratory. In this article, a case study of the development of a modern power system laboratory at the University of South Australia is presented and discussed.

INTRODUCTION

Nowadays universities in Australia are increasingly forced to operate on a financial business model as the government is gradually reducing funding for the universities. Consequently, many universities face a problem of having out-dated laboratories in general and, in particular, the laboratories for teaching electrical power engineering courses as these laboratories require high investments. However, the number of students studying electrical power engineering is in decline and universities are hesitant to commit to such investments when it is unlikely the direct costs will be recovered by the university. Unfortunately, this is a short sighted strategy that will have a long term negative effect on Australian economy.

The use of various software packages for power systems simulation is common practice at universities and in industry. So, many universities legitimately opted to use only simulations and not to run hands-on laboratories in power systems courses. However, hands-on work is equally important in enhancing students' learning experience and providing essential skills in this field of engineering. This article presents a development of an electrical power engineering laboratory in collaboration with industry partners with a prospect to convert it into a remote laboratory at a later stage and share it with other tertiary institutions.

THE NEED FOR REFORM OF POWER ENGINEERING EDUCATION

Teaching electrical power system courses traditionally relies on teaching electrical machines, power systems analysis and power electronics. Knowledge of the fundamental concepts in these engineering fields are still relevant and very important for industry, so first and second generation of machine laboratories dating from 1930s and 1960s are still in operation at many universities [1][2].

This was also the case at the University of South Australia (UniSA) until recently when these laboratories ceased to be used mainly due to safety reasons. Although the wiring in the laboratories was upgraded and safety was significantly improved, it was felt that the laboratories did not comply with today's electrical safety standards.

On the other hand, the power industry is currently going through unimaginable transformation due to new developments in digital technology, and the necessity for green energy solutions. This puts pressure on universities to modernise the power engineering curriculum in order to prepare engineering graduates for the future career in modern power industry. A number of universities are revising their power engineering curricula to include topics relevant to modern power engineering like:

- renewable and distributed energy generation;
- energy storage;

- components and operation of smart grid;
- computer networking, data communication and cyber-security;
- data collection and information extraction for decision making.

It is evident that power engineering has become a multidisciplinary field and practicing power engineers need skills ranging from traditional power systems topics related to components of power systems and their operation, including electrical machines, transmission and distribution systems, protection systems, through physics of energy generation from renewable sources and performance characteristics of energy storage media, computer engineering and data communication in modern digital technology including wireless networks protection of networks and data.

The need for computer science skills should also be mentioned in terms of the use of intelligent techniques to operate the physical system economically, safely and reliably, but also in terms of collecting and interpreting data for economic benefits including informed participation of customers.

Consequently, it is becoming more challenging for staff to teach power engineering as those who have expertise in power engineering rarely have an adequate knowledge of information technology (IT) for teaching these modern topics, so power engineering graduates find themselves working in industry, which requires knowledge and skills not only in traditional electrical power engineering, but also in communication engineering, computer system engineering and IT.

The power engineering community is asking where this new generation of power engineers with skills required to design and operate the inevitable smart grid of the future will come from and how the electrical power education can be reformed to prepare graduates for this new role in reshaping power industry adequately [3]. The educators agree, there is not only the necessity for the change of the curriculum, but also a heavy demand for staff development if the new curriculum is to be delivered in an integrated way. There are a number of initiatives worldwide that are trying to address this problem [4-10].

MODERN POWER ENGINEERING LABORATORIES

While restructuring the power engineering curriculum, many universities took an opportunity to update their power engineering laboratories. It is not surprising that most new power engineering laboratories include the smart grid technologies as the core of a modern power system and many include renewable energy generation [11-22].

As power engineering is becoming multidisciplinary field, the laboratories developed for teaching power engineering can also be used in teaching other topics including communication, computer science, artificial intelligence, cyber-security, etc. Having this in mind may help academic staff teaching power engineering justify investment into these laboratories as they can be used by broader teaching and research communities, especially, when they are shared on-line by different departments of the university and different universities.

However, development of such laboratories necessitates significant investment of resources not only financial, but also in terms of staff efforts and multidisciplinary skills rarely possessed by one person. To make this development possible the UniSA decided to create a team, which includes members from several departments and also involves industry partners to make students learning experience more industry relevant.

DEVELOPMENT OF NEW POWER ENGINEERING LABORATORY AT UNISA

The basic architecture of the laboratory is shown in Figure 1. It includes renewable generation (wind and solar), energy storage (batteries), hardware simulated distribution network and distributed loads integrated into a supervisory control and data acquisition (SCADA) system that also provides human machine interface (HMI) that enables users to interact with the system. Interface with the physical layer of the power system is accomplished through programmable logic controller and other intelligent electronic devices (IED).

The laboratory does not include the transmission part of the power system, but may be added later. The system is designed with the aim to be expanded over the time, including the addition of different types of renewable sources generation (e.g. fuel cell) as new technologies develop and become available and affordable. The same applies for loads. It is envisaged that the new loads will be added over the time; in particular, more efficient loads will be used to replace old loads with a final goal to make the laboratory self-powered (green); so, no power from the external power grid will be used.

A number of companies offer educational systems for teaching electrical power systems [23-26]. However, it has been decided to develop one in collaboration with local industry, because of the previous good experience in such collaboration [27] and because of the University's strong interest in developing new collaborative projects and strengthening the links with industry in both teaching and research activities.

In addition, this development gives a platform for a number of projects both at undergraduate (e.g. final year research projects) and at postgraduate levels (e.g. Masters and PhD). Because of its complexity, it gives students from different disciplines numerous opportunities to collaborate and to develop their knowledge and skills and at the same time to develop a system that showcases the capability of the students to industries that employ UniSA graduates.

Although the project is at its initial stage, a number of students and staff are already working on the design and the development of a business case to be used as a proposal for acquiring the funding.

The laboratory will be used as an integrated learning environment for running traditional experiments on electrical machines and power systems operation and control, but also for new experiments on renewable energy generation, energy storage, SCADA implementation, design of a protection system utilising digital protection relays (e.g. SEL311C that is already own by the University) and implementing concepts of smart grid, which opens up limitless educational opportunities for teaching and research at various levels and in various fields.

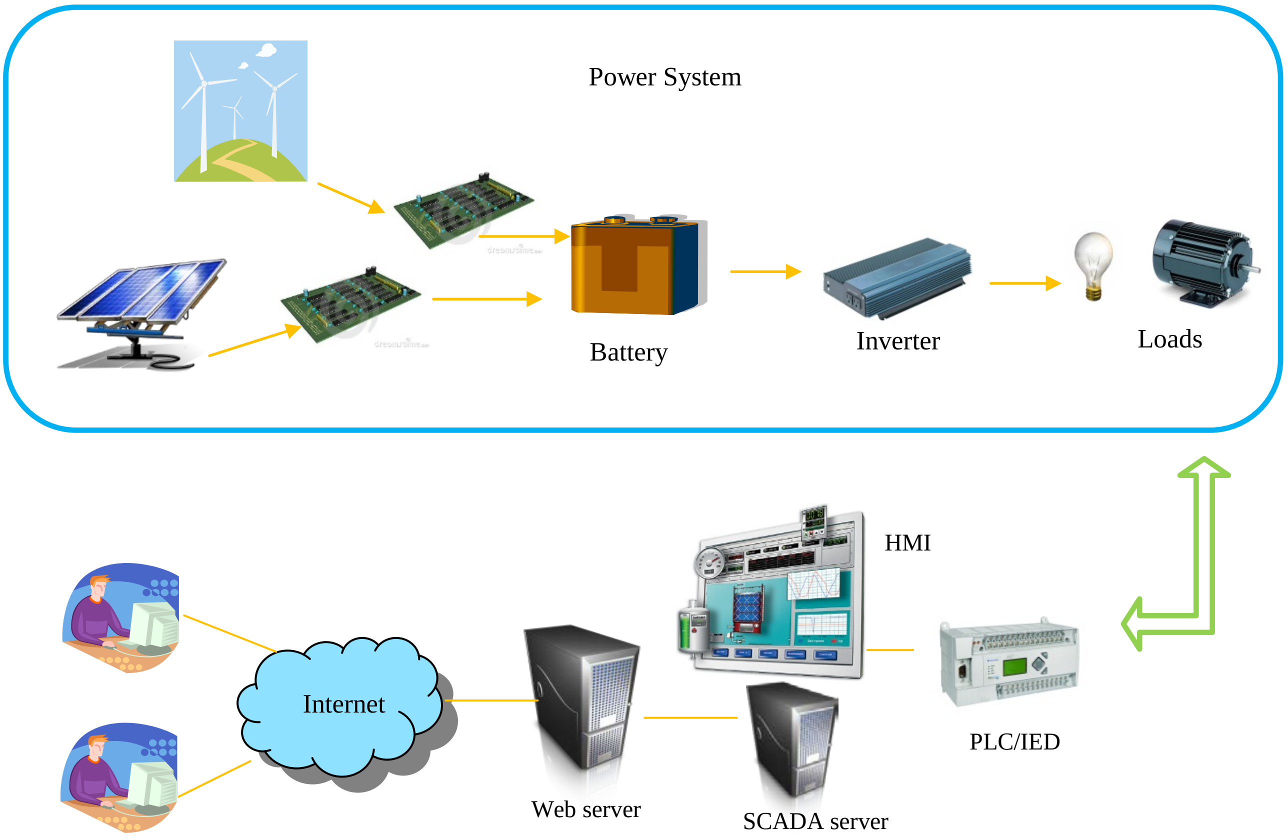

Figure 1: Laboratory basic architecture.

CONCLUSIONS

In this article, an initiative to develop a modern power system laboratory has been presented. As it is in the initial stage, the success of the project cannot yet be claimed, but the need for such a laboratory is emphasised and opportunities that it may open up for teaching not only power engineering, but also other engineering topics is presented. The outcomes of this development will be presented in future publications.

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