Development of Online Power Laboratory with Renewable Generation

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Abstract—**Many universities worldwide use outdated laboratories for teaching power systems courses. This is understandable taking into account the high cost of equipment required for upgrading these laboratories. One solution to this problem may be the development of online remote laboratories that can be shared among universities. This will not only offer the reduction of cost but also the utilization of modern technology that meets expectations of the new generation of students. In this paper we present the development of one such laboratory that also aims to incorporate renewable generation technologies**

Index Terms—**remote laboratory; power systems laboratory; renewable energy.**

I. INTRODUCTION

Many universities have power engineering laboratories that are obsolete and need to be updated. Some universities still use the 1st and 2nd generations [1] of power laboratories which have perfectly functional equipment and serve the purpose of providing the fundamental educational objectives concerning electrical power systems including topics on electrical machines and transformers, and power electronics and drives. However, they do not satisfy today's safety standards, and certainly do not look appealing to new generation of students who consider all equipment older than 10 years as outdated. In most cases they are right, as education including teaching electrical power engineering is going through a phase of rapid change due to the advancements in technology.

In 1980s and 1990s many of the 3rd generation of power laboratories were developed with at that time modern computerized measurement data acquisition set-ups like ones described in [1-3], just to mention some. With the recent developments in technology and its utilization in power industry, it seems that a new generation of power laboratories is now needed. However, it is not an easy task to invest in and build a power engineering laboratory that will be considered as a modern educational laboratory at least for a foreseeable future. Krein and Sauer [1] postulate nine objectives that a modern power laboratory shall meet, including the use of industry grade equipment, and providing flexible design that supports evolution of the laboratory over the time to cater for the changing educational needs.

Updating a power engineering laboratory requires high investments. However, the number of students studying electrical power engineering is in decline and universities are hesitant to commit such investments when the financial return is unlikely to eventuate.

One of the solutions is the development of remote laboratories that can be shared among universities. Lately, the remote laboratories are becoming common features at many universities due to their convenience of use both by teaching staff and by students. They allow staff to perform demonstrations of experiments during lecture classes. They also enable students to perform experiments on real equipment from anywhere at any time and what is even more important to repeat experiments as many times as they like or need to in order to satisfy their learning outcomes.

II. NECESSITY FOR CURRICULUM CHANGE

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 [4, 5]. 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 do not comply with today's electrical safety standards.

On the other hand, the power industry is currently going through rapid transformation due to new developments in digital technology, and the necessity for green energy solutions. This puts a pressure on universities to modernize 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:

a) renewable and distributed energy generation;

b) energy storage;

c) components and operation of smart grid;

d) computer networking, data communication and cyber-security;

e) data collection and information extraction for decision making.

Evidently, the 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. At last, the need for computer science skills should 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 Information Technology (IT) knowledge necessary 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 to reform the electrical power education to adequately prepare graduates for this new role in reshaping power industry [6]. The educators agree there is not only 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 [7-12].

III. MODERN ELECTRICAL POWER LABORATORIES

Our review of the existing modern power laboratories shows a number of developments related to:

a) smart grid laboratories [13-20]

b) renewable energy laboratories [15, 21, 22]

c) SCADA (Supervisory Control And Data Acquisition) integrated laboratories [14, 22, 23]

d) remote power laboratories [21, 22, 24]

The list above shows that power engineering is becoming multidisciplinary field and the laboratories developed for teaching power engineering can be used in other areas including, communication, computer science, artificial intelligence, SCADA security, etc. Having this in mind can 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 online 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 we decided to create a team, which includes members from different departments and also involves industry partners to complement our academic skills with their industry based skills and expertise in the design and implementation of a modern power system laboratory.

IV. DEVELOPMENT OF ONLINE POWER LABORATORY

A number of companies [25-28] offer commercial-off-the-shelf (COTS) educational systems for teaching laboratory component of electrical power system courses. However, we have elected to develop our own laboratory in collaboration with the local industry because of the University's strong interest in developing new collaborative projects and strengthening the links with local industry in both teaching and research activities. This development also gives a platform for a number of projects both at the undergraduate level (e.g. final year research projects) and at the postgraduate level (e.g. masters and PhD) and builds up on our previous successful experience with the development of a number of remote laboratories by staff and students at UniSA [29, 30]. Due to its complexity, the system gives students from different disciplines the opportunity to collaborate and to develop their knowledge and skills and at the same time to develop a system that showcases the capability of our students to industries that employ our graduates.

The basic architecture of our laboratory is shown in Fig 1. It utilizes the distributed electricity generation including renewable energy sources like photovoltaic solar panels and possibly a small wind turbine generator; battery for energy storage, hardware simulated power lines and distributed loads integrated into a SCADA system. At this stage, the laboratory does not include high voltage power lines due to practicality and safety issues, but they may be added in the future. The system is designed with the aim to be expanded over a time, including addition of different types of electricity generation from renewable sources (e.g. fuel cell) as new technologies develop and become available and affordable. The same applies for loads. It is envisaged 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.

The system is in its initial development stage where a prototype of a small hybrid power system will be constructed that will include 1.5kW wind turbine generator; 1.5kW capacity of photovoltaic panels; both static and dynamic variable loads (lights, heather, motors) that can be switched on and off remotely and a battery bank for energy storage. It will also include the necessary support equipment like controllers/inverters and dump loads. The system will initially operate off-grid.

Components for this system are available as COTS from different suppliers. One such company is Australian Wind and Solar [31], which sells components, but also provides design of on-grid or off-grid systems, wind or solar or hybrid. The proposed hybrid off-grid system would cost about AU$32,000. A number of instruments will be inserted for measurement, and remote monitoring and control, which are not normally part of a COTS system, for students to be able to perform experiments on the system. This would normally include measurement and also logging of date such as values of current, voltage, power, power factor and energy. A smart meter is planned to be used to make system adaptable for future experiments that may involve smart grid technologies. Smart (digital) protection system will also be included.

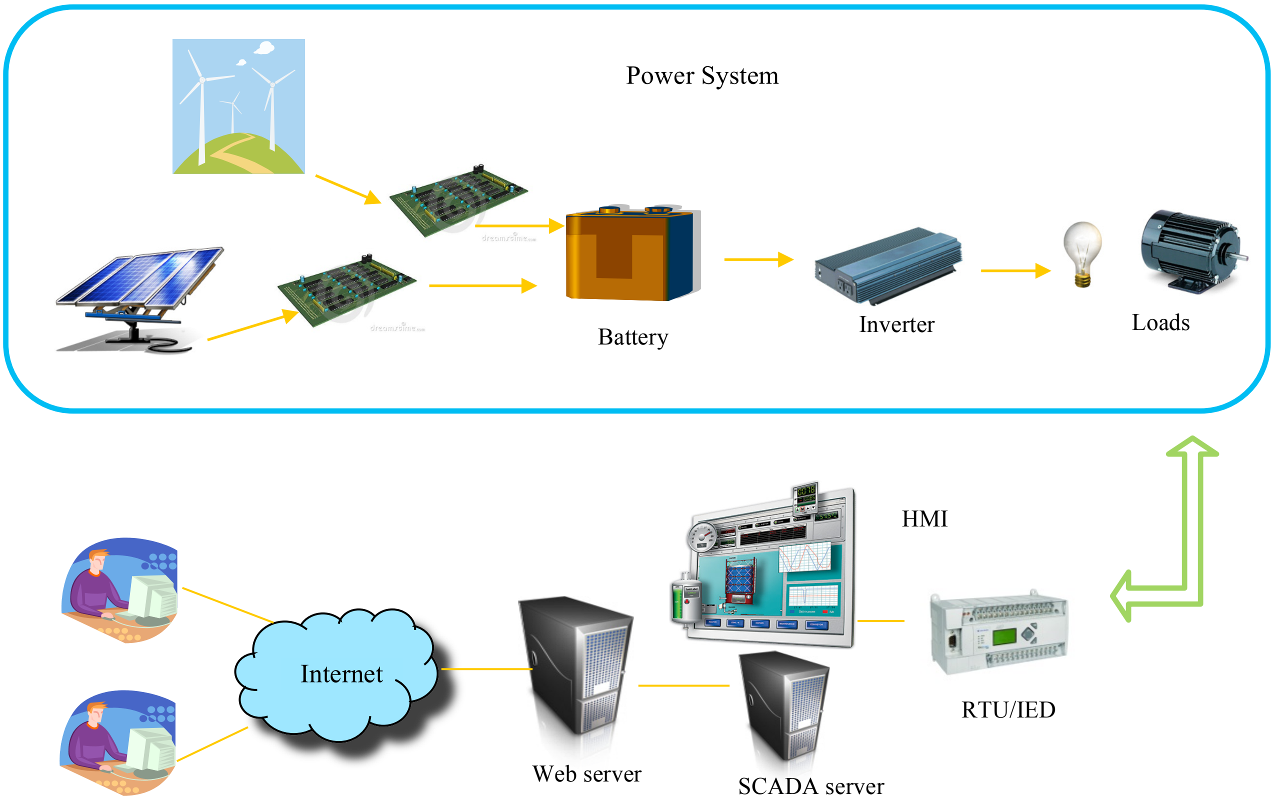

Figure 1. Basic system architecture

The system will be integrated into a SCADA system that will not only enable monitoring and control of the system, but also remote access over the internet. The University already has a license for the Wonderware InTouch SCADA software [32], which will be used for this purpose. Students studying power engineering stream learn to use this software to develop SCADA applications in the course Mechatronic System Integration. So, they will be familiar with the software. However in the case of undergraduate power laboratory experiments students will not be required to develop applications; rather, they will just monitor and operate the system from remote locations and collect data for analysis

Unlike undergraduate students, postgraduate students will be able to perform more advanced assignments and mini projects including creating SCADA software applications, configuring communication interfaces of smart devices into the SCDA system, implementing smart grid technologies into the system, etc.

V. CONCLUSIONS

This article presented a proposal for the development of a new power engineering laboratory that will be developed in four stages over a number of years, which is a common practice for systems of such complexity [33]. The 1st stage has already been developed as part of a final year project in collaboration with the local electrical power distribution company SA Power Networks. Now the expansion as well as the work on providing the remote access is in the progress through another two final year projects and outcomes will be reported in future publications.

This new laboratory will not only provides safe working environment for students, but also enables students to acquire knowledge and skills necessary for engineering graduates if they are to successfully work in modern power engineering industry.

In addition, one such laboratory opens opportunities for students from other disciplines to develop and practice their skills (e.g. computer engineering) and to contribute to the development, expansion and the improvements of one such complex system.

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