2006-826: DEVELOPMENT OF A WEB-BASED LEARNING AND INSTRUCTION SUPPORT SYSTEM FOR RENEWABLE ENERGY SOURCES/HYBRID POWER SYSTEMS COURSES

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1. Introduction:

This paper details the ongoing effort focused on the development and implementation of a Web-based learning and instructional support system and materials for a sequence of two courses in the newly established program in Alternative/Renewable Energy Technology at the College of Engineering, Wayne State University. The first course, Fundamentals of Renewable Energy Sources, is also the pre-requisite for the second one, Hybrid Power Systems (HPS) –Analysis and Design. These courses are offered in the Winter 2006 term. The support system for these two courses will include course materials, remote data acquisition modules, and simulations/laboratory experiments[1-5]. The emerging technological advances in the renewable/alternative energy and the steadily increasing applications and their use by the power industry has instilled the critical need for engineers and technicians with technical skills tailored to these advances and to close the competence gaps in the areas of distributed generation (DG), hybrid power systems (HPS) and renewable/alternative energy technology. The development of these courses addresses these critical needs. Developing the proposed courses and responding to the changing needs of society in this area is a challenge, and will greatly enhance the effort of the College to foster interdisciplinary and professional interaction in the context of education, research and community development. The courses are to be offered as elective at the 5000 level, and hence are considered graduate courses. Qualified undergraduate senior students also can take them, but in their case some of the topics and requirements will be omitted.

Graduate students in Engineering Technology receive a broad training in mathematics, computing, and engineering and technology, through core and elective courses. Power engineering courses, in the new context of energy and environmental concerns and renewable energy technology courses will be well appreciated. The Division of Engineering Technology at Wayne State University plans to establish, in the near future, an undergraduate program in alternative energy technology. This program is intended to bridge the gap between 2-year college level programs in this area and the already established graduate level program in alternative energy technology. As part of this effort, in Winter 2006 term, two courses in renewable energy sources and hybrid power system (AET5500 – Renewable Energy Sources; and AET-5600 Hybrid Power Systems – Analysis and Design), both at senior undergraduate/graduate level are offered as pilot-courses in renewable energy/hybrid power systems.

Hybrid power systems combines two or more energy conversion devices that, when integrated, provide: (1) additional advantages over those devices operating individually, and (2) a synergism that yields performance that exceeds the sum of the components[6]. **Hybrid power configurations** are likely to represent a major percentage of the next generation of advanced power systems, due to high efficiency, modularity, flexibility, and low level of pollution[6-15]. These systems are one of the most suitable approaches in design and implementation of the distributed generation and hybrid power systems[7,8]. Characteristically, DG is a combination of small sources of electric power generation and/or storage systems, typically ranging from less than one kW to tens of MW. DG is not part of a large central power system and is located close to the load. DG includes biomass based generators, wind power systems, combustion systems, fuel cells, micro-turbines, concentrating solar power and photo-voltaic (PV) systems, combustion turbines, wind turbines, engines/generator sets, small hydro plants, and electric energy storage systems and technologies[9-20]. These can either be connected to the grid or operate independently. Distributed generation is considered to be the new and more suitable approach to providing solutions for socio-economic energy problems that have taken on considerable importance as we move into the new millennium. The enhanced efficiency, environmental friendliness, flexibility and scalability of the emerging technologies involved in distributed generation have put these systems at the forefront to provide power generation for the future[8-10]. Overall, the potential efficiency of any configurations of hybrid power systems has been estimated to be about 80% by a generalized model[13].

1.2 Course Description

The courses consist of lectures, fundamental design exercises, a mid-term exam in the eighth week, and a design project due during the final exam week (the 16th week). As much as possible, all efforts will be directed in putting the students in the position to being a design engineer. The classes are scheduled to meet twice a week for two- and one-hour lectures. The fourth credit hour was allocated for out-of-class research, computer applications, and team design work. The lectures cover theory and design calculations and leave lots of time for answering questions and mentoring the students. In addition to answering course-specific questions, perspective discussions focus on economic and environmental constraints, marketability, distributed generation advantages, power quality issues, etc. We structured these courses to incorporate theory, design aspects, practical applications, and power quality and environmental issues. The structure is modular, and each module was designed to be self-content. Table 1 details the course topics and the course syllabuses[8,9]. Design homework and exercises are assigned to the students during the first eight weeks of the term. Initial homework assignments focus on theory and concepts of renewable energy sources, hybrid power systems, and distributed generation aspects. The course enrollment is a mixture of senior undergraduate and graduate students (12 graduate students and 3 senior undergraduate students), so project teams will be assigned to balance them. Each design team will be allowed to select their own team manager.

Course Outcomes: ***After completing this course, students will be able to do the following:***

1. Computation and analysis of renewable energy sources and energy conversion.
2. Select, design and analysis of the hybrid power system configuration, characteristics and optimization and a HPS, and HPS components and their operation characteristics and principles.
3. Compute and estimate available wind and solar power at a specific site.
4. Design and analysis of various configurations of hybrid power systems.

5. Analysis and computation of HPS components (wind, solar/PV, fuel cells and batteries, micro-turbines, etc.).
6. Understand principle of operations of stand-alone and grid-connected hybrid power systems, record experimental data, display the results and write formal laboratory reports to document the project.
7. Communicate clearly, concisely and correctly in written, oral and visual forms (as proven in tests and labs), which effectively convey ideas and concepts to peers and faculty, using proper technical terminology.
8. Give the students an appreciation the current state of power electronics and their applications and a realization that there is considerably more to be learned about this subject.

Table 1 – AET 5500/5600 – Course Syllabus:

Hour	Topic	Syllabus
6	Introduction, Basic Concepts of Power Engineering	Instructional Objectives. Matlab Primer, Review of Mechanical and Electrical Concepts, Electricity Generation, Data Analysis and Statistics, AET and Environmental Concerns
12	Wind Energy Systems	Types of Wind Turbines; Principles, Operation and Characteristics; Wind Statistics and Measurements; Wind Turbine Performances
10	Photovoltaic/Solar Engineering	Solar Resources; Measurements; Photovoltaic Materials and Electric Characteristics, PV Arrays; PV System Types, PV Characteristics and Performances
10	Fuel Cells, Battery and Energy Storage	Battery Types and Characteristics; Battery Storage Capacity and Sizing; Hydrogen Energy; Fuel Cell Principles and Operation Characteristics, Types of Fuel Cells; Other Energy Storage Systems
10	Electricity Generation. Power Electronics	Power Electronics, Rectifiers, Inverters and Converters, Control Systems from Wind and Solar Systems; Power Conditioning Units.
6	Distributed Generation	Power Quality and Distributed Generation
12	Hybrid Power Systems - Projects	Stand-Alone and Grid- Microgrid-Connected HPS

1.3 Laboratory Work

Laboratory Experiments: In general, the laboratory experiments are designed to:
a) Reinforce and support the lecture-based course;
b) Emphasize the importance of corroborating the results of laboratory measurements;
c) Expose the students to the measurement techniques used in the industry in general.
To achieve these goals, we decided to divide the laboratory experiments in two broad categories: 1) dealing with basic experiments and techniques, which will strengthen the student knowledge in general areas of alternative energy technology/renewable energy resources, and 2) projects in alternative energy technology and hybrid power systems.

Projects: The importance of the projects in scientific and technological education is well established[2-5]. A typical project will involve selection of HPS components (wind system, solar/PV system, fuel cell and battery, power conditioning unit, controllers, etc.), characteristics of each component, optimization, etc[6-20]. Each project will be assigned to a team of 3 to 4 students. The students will be free to form the team, with the only requirement that no more than one undergraduate student to be in one team.

Typical project samples (about 12 hours):

1. Study and Analysis of the Performance of a Remote Wind-Diesel-Fuel Cells Power System.
2. Power Control Strategy of a Solar/Wind Generation System
3. Analysis and Design of a Standalone Wind-Solar Power System.
4. Operating Methods Using Prediction Techniques of a Photovoltaic-Diesel Hybrid Power Generation System.
5. Design and Analysis of Adaptive Control of a Fuel Cell-Microturbine Hybrid Power System.
6. Study of a Non-Interconnected Grid Wind-Power Fuel Cell Hybrid System.

2. Development of Web-based Learning and Instruction Support System for ATE5500 Alternative Energy Technology/Hybrid Power Systems – Analysis and Design course.

In recent years, there also has been a considerable growth in the use of educational materials over the World Wide Web (WWW)[2]. While remaining a super database of information by connecting the world together with the aid of a user-friendly interface, the Internet is being transformed into a brand new educational model for almost every business sector. The Internet is full of rich media in text, image, animation, video and audio formats, and also provides various tools to assist communication among users. These tools include File Transfer Protocol (FTP), Electronic Mail, ARCHIE, TELNET, On-line Chat, Bulletin Board, Discussion Groups, Digital White Board, On-line Meeting, Web Phone, Web Radio, Web Fax, Chat Room, Virtual Reality, etc. Most of these tools can be further integrated with the Internet to become an efficient instruction and educational environment. This development encourages educators to develop these emerging markets. Due to the popularity of the Internet, most instructors use the network to host their teaching materials.

The main objectives of this project are to develop and implement a web-based learning and instruction support system for new project-based AET courses[1-6]. In order to meet the increased demand beyond the laboratory hours, the Web-based instructional support, software and hardware virtual laboratory will be created. Using the MATLAB, IDL and LabVIEW software packages we are underway to develop a part of the system components, during Winter 2006 term. The support system will be completed during the Summer and Fall of 2006 terms. By using this course-support system, students can learn in a self-paced and well-customized mode. The instructors can easily and efficiently maintain, improve or update the web-based contents through the web browser and other Internet tools.

2.1 Web-based Learning and Instruction Support System.

A web-based learning and instructional support system and materials will be developed for these two courses. The support system for these courses will include course materials, remote data acquisition modules, and simulations/laboratory experiments[1,2]. The course materials are in a HTML format and accompanied with text, diagrams and images, simulation programs, and computer aided analysis and design tools. This Web-based learning and instruction support will be used to assist with the instruction, distance learning, laboratory practice and hybrid power systems, computer aided analysis and design. There are many reasons to use the Internet as a support in teaching this course. First, the Alternative/Renewable Energy is evolving rapidly as an advanced academic field so that the content of a textbook tends to get outdated more quickly compared to traditional academic fields. Second, the renewable energy/alternative technology is an inter-disciplinary field covering topics such as meteorology, energy conversion and power systems, power electronics, electric generators, radiative and heat transfer, solar energy/photovoltaic arrays, fuel cells and batteries, diesel engine and micro-turbines. Third, the cost of setting, upgrading and maintaining traditional hard course-supporting laboratories in the areas of alternative/renewable energy is quite high. Thus, high quality text and reference type of materials can be delivered through the Internet, updated and changed at regular intervals. The support system is designed and intended for tutorials, discussions, and/or collaborations among students. The laboratory experiments and design projects will be developed by using software packages, available in WSU College of Engineering, such as MATLAB/Simulink, LabVIEW and Interactive Data Language (IDL)[1-5]. An important part of second course, dealing with HPS, will be included in capstone design projects[2-5].

Courseware: The courseware outlined by chapters covers the basic principles of renewable energy sources up to the more advanced sections including hybrid power systems, distributed generation, power electronics and control, energy management, and data analysis and processing. The courseware contains text, figures and diagrams, Matlab and LabVIEW simulations and is delivered via the **GradePoint CoELive** environment (a real-time instructor-led suit of on-line tools to help design, create and deliver synchronous and asynchronous class). The courseware will be hosted in a Web server to allow multi-user, including on-line exam and homework. All materials can be saved in a database server. The main features of CoELive software, include among others: Integrated Email and News Servers, Bi-Directional communication, Integrated classroom, Video Broadcasting, Interactive Board Capabilities, Student Project Management, Real-Time Classroom Recording. These tools will be helpful in facilitating the on-line course development.

Virtual AET Laboratory. The main attributes of our LabVIEW and MATLAB based virtual laboratory are: (a) the virtual Instruments (VI's) and HPS components operate on Windows-based platforms that can be found in the majority of computers used by students, (b) the distributed programs are free-ware or Wayne State has license, resulting in a low implementation cost, (c) a modular and expandable architecture was adopted for software components, linked with CoELive environment, thus giving the users the option to extend system component capabilities and/or the types of virtual devices, and (d) the incorporation of the wind and solar time series for a number of sites, selected for design projects.

2.2 System Specifications

Approach to System Components, Instruments, Procedures, and Applications: The system must support students in familiarizing themselves with problems and technologies used in wind and solar data and other renewable sources through the simulators of real instrumentation, devices, components, circuits and systems. Senior undergraduate and graduate students will learn to create new instrumentation, procedures, and HPS components by using the capabilities of LabVIEW and MATLAB software packages. They also will learn data analysis, statistical methods and processing techniques used in solar and wind energy.

Student Typologies: Different kinds of students with different needs must be supported, such as undergraduate and graduate students, as well as practitioners from industry.

Adaptability to User Needs and Scalability to User Level: The system must adapt operations and support to specific users. Students with different backgrounds and needs must be allowed to participate, without being overwhelmed by too much information. The system must scale features of resource view according to the level of competence, experience, and confidence of the students.

Tutoring Aids: The educational system must support different types of interactions between students and educators. Tutors in laboratories and classrooms can provide assistance to students during classes. When the student alone is using the simulation environment educational supports will be appreciated. On-line help for using the simulation environment and other system resources can be introduced by using standard programming techniques available in the user interface. Multimedia pages are attached to each object of the workbench front panel to explain the meaning, theory, features, and use of the selected components. Possible links can also be placed to more extensive descriptions on Web sites. Multimedia and hypertext technologies through web or CD-ROM distribution allow for realizing an electronic book on methodologies, instruments, and hybrid power system components that can be used by students during the class and laboratory. This book will refer on-line to the distributed educational environment and remote sensing resources to provide examples of theory, design methodologies, and examples of projects. The student can thus experiment immediately in the virtual environment.

User Accessibility: The main features of user accessibility are: a) *User Friendliness; b) Simplicity of Accessing the Laboratory and Course Resources; and c) Different Accessing Technologies,*

2.3 Software Capabilities; Real-Time Operation and Distributed System Engineering.

Software Cost: The software developing tools are based on graphic, object-oriented programming methods make this job easier and more feasible to a wider population. Development, upgrading and maintenance cost will also be reduced.
Simulator Components: Using standard virtual environments for simulation and simulator development makes creating and testing new environments simpler and cheaper, and it will also increase the quality, correctness, portability, adaptability and extendibility of the experiments. The availability of a component library and use of standard design techniques will allow for re-using and enhancing development and cost**.**
Real Time Operations and Constraints: If the system to be analyzed, measured or controlled is connected to the student's computer through suitable (DAQ) cards real-time operation of the virtual system will be possible.
Modularity and Expandability: It is relevant for the simulation system and the component library to allow the combining of individual components easily to create the workbench or new components without any need of software development/adaptation. New components can be added, without library rebuilding or restructuring.
System Portability and Interoperability: The simulation environment and the component libraries should be portable on different hardware platform and operating systems.
Capability of Sharing Resources and Experiences with other Universities, Colleges and Companies: The global communication network and CoELive facilities will allow for allocating simulation and remote acquisition programs on different servers.
Security and Safety: The access through the Internet must preserve the integrity of data and systems, and the access will be allowed only to authorized users.

2.4 Virtual Laboratory Implementation:

A workbench will be composed, by using the simulation engine of power system components, controllers, measurement systems, as well as wind and solar measurement database[2-5]. The full implementation of the laboratory will be completed during the Fall 2006 term. Different types of virtual components and data analysis and signal processing procedures will be available to support different structures of the hybrid power systems:

- Instruments, Models of different Types of Sensors and Traducers;
- Electrical Generators; Wind Turbines, Fuel Cells, Batteries and PV Cells/Arrays
- Micro-Turbines, Hydro-Turbines and Diesel-Engine Generators;
- Controllers, Sun Trackers, Inverters, DC-CD Converters, Battery Chargers and Power Conditioning Units;
- Data Analysis, Statistical Methods, and Graphic Procedures and Subroutines.

Simulation engine, sampler, and virtual components are created in LabVIEW, a widely used virtual environment for measurement areas, while the data analysis and signal processing procedures and algorithms will be implemented in MATLAB and IDL software packages[1-5]. The engine is designed as an executable program that contains the run-time support of LabVIEW and interprets the selected components' definition to realize a specific configuration. Definitions of components will be created by the faculty and/or by the senior undergraduate or graduate students supervised by the faculty. These definitions will be stored in files in the component database of the distribution server. They are in a format that can be read and interpreted by the LabVIEW run-time support. Interpretation and use of the Web technologies will allow for portability and interoperability. The components and the engine and the run-time authorization checking are stored, held, and managed in the distribution server.

LabVIEW, a data-flow graphical programming language, together with MATLAB, will play an important role in the development of our virtual system as well as in the actual on-site laboratory. The main objective behind our approach is to create an environment for experimentation where undergraduate students with little or no programming experience will be able to experiment and quickly to arrive at valid experimental results and conclusions. Experiments can be performed by students at home or in any remote place connected to the internet and can be repeated in the lab using physical instruments, circuits and devices.

3. Summary and Conclusions.

This paper presents the on-going effort of our division to develop new courses and a program in area of renewable energy technology and hybrid power systems. This endeavor is part of new undergraduate program in renewable energy technology that will be implemented by in the near future. A course support system and web-based learning support environment is underway to be developed during the 2006 year, being for the first time offered during Winter 2006 term. The structure of these courses is modular to allow the flexibility of the topics length and to remove topics or to add new ones. These courses are scheduled for the Winter 2006 term. Due to the multidisciplinary and rapidly evolving academic nature of these subjects the courses were designed as project-based courses. Our approach will also include the development of general-purpose user interface and simulation system for experimenting and will be developed to be independent of physical instrumentation and computer platform, with on-screen lab manuals, and reports written and graded on screen. The complete implementation of the support system will be finish during the academic year 2005-2007.

Besides the usual student evaluation surveys run by the university, at the end of each term, the faculty intends to run own surveys, one during mid-term exam and the other during the end-term project presentation, in order to have extra student feedback, course evaluation and assessment.

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