Suggested Course in Multi-Disciplinary Renewable Energy Management

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Abstract- Due to the high rate of fossil fuel consumption and depletion of traditional energy sources, a global energy crisis is estimated to occur within the next 60-100 year. The quest for a new energy sources has necessitated the deployment of renewable sources of energy. This has brought to the forefront the need for effective management of both traditional and non-traditional sources. Preparing engineering students to fully understand the nature of the impending crisis and be equipped for it is therefore imperative. In this paper the authors propose a multi-disciplinary course in energy management in the Electrical and Computer Engineering curriculum. Therefore, the objective of the course is to introduce to the undergraduate and graduate students, state of the art energy management principles and algorithms. The proposed course will cover many concepts of the available renewable energy sources management techniques. In addition, the application of artificial intelligence techniques such as evolutionary programming, and artificial immune system in energy management will be introduced. This course will be offered as an advanced level course following the introductory renewable energy course that the authors are currently teaching in the Electrical and Computer Engineering Department. In addition to graduate and undergraduate students, the proposed course is expected to attract engineers from the local industry as well.

Keywords: Renewable energy, energy management, evolutionary programming, immune system.

INTRODUCTION

Because of the ever diminishing supply of fossil fuels worldwide, the realization has grown over the past few decades that, (a) sources of energy that are not fossil fuel based (renewable sources) should be investigated and if possible integrated into the energy supply system and (b) make every attempt to improve the energy efficiency of those sources that are fossil fuel based. Scientists worldwide have focused attention on and contributed to the development of renewable energy sources such as wind turbines, hydro power pants, photovoltaic sources, and fuel cell and fission based power sources. Taking advantage of these developments, concentrations of renewable sources have been established regionally all over the world. Examples of such concentrations are for instance, the wind generator 'farms' in California and in the Scandinavian countries. High powered solid oxide fuel cell (SOFC) based sources have been deployed as portable power generating units by the US government agencies. On a smaller scale, private individuals and small businesses have installed solar powered and wind powered sources as a cost cutting measure. As confidence in these sources grows among the public it will not be long before the utility companies start looking at these energy sources as viable supplemental sources for the generation of electrical energy. In addition, a hybrid combination of renewable energy sources can be located in a reasonable sized locality which already has grid connectivity and a reliable electric power distribution infrastructure. Clearly, the significance of developing such a hybrid 'mini-grid' of sources is to provide the utility authority a cheaper and environmentally less deleterious means for the generation of electrical energy. Extensive integration of renewable energy sources will present challenging problems to utility authority such as the management, control and integration of such a hybrid combination of sources with the existing supply structure. The utilities manage and control the 'classical generating stations' utilizing time tested software. The main objective of this software is to develop operational plans that minimize operational cost. The question that arises here is how best to integrate the 'mini-grid of sources' with the larger grid system.

Renewable energy courses at the undergraduate and graduate levels in most Electrical Engineering curricula focus only on teaching brief introductions to this emerging technology. Student in those courses do not get enough

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experience on how to deal with and manage a group of renewable energy sources connected in parallel with the local grid or feeding one load in a standalone mode. To face the energy problems of the future, and mitigate the effects of the global energy shortage, engineers have to equip themselves with all the necessary tools for effective use and management of available natural renewable energy sources.

This paper is focused on introducing a new and innovative energy management course that can be integrated into the Electrical Engineering curriculum at the undergraduate and the graduate levels. Section Two of the paper gives an overview of the renewable energy management techniques. Course material is introduced in Section Three, and conclusions are presented in Section Four.

OVERVIEW OF RENEWABLE ENERGY MANAGEMENT

Managing hybrid renewable energy sources has been the objective of recent research. However, it is difficult to know the overall effectiveness of a renewable energy system that has multiple renewable sources and several energy storage systems. Energy management depends on many factors and processes that include source type, location, source efficiency, economic cost, energy conversion/processing, emission, and supply/demand of energy. These factors and processes in addition to their interactions are complex and contain many uncertainties [1]. Many models and techniques have been employed in the literature to manage two or three renewable energy sources [2]-[6]. But there is a lack of formalized methodology to integrate these models into a general framework based on optimal economical operation of the system.

Effective integration of renewable energy sources requires the development of an energy management paradigm, which allows the user to minimize the overall cost of energy by optimally operating their renewable energy sources, while maintaining connectivity with the grid. In addition, the energy management program should be flexible enough to accommodate any changes in the number of deployed sources. To implement such a paradigm, effective and robust techniques based on cutting edge artificial intelligence techniques must be employed.

The course material and description to follow will be based on two artificial intelligence techniques for the management of the energy of a variety of renewable energy sources and energy storage devices contained in a minigrid. The architecture of the minigrid system is described below.

SYSTEM ARCHITECTURE

The system will be configured as a hybrid system that includes PEM fuel cells, microturbines, photovoltaic modules, and wind turbines. In addition, a hydrogen production and storage system will be used to store the excess energy from the photovoltaic modules and wind turbines in hydrogen form, figure 1. The hydrogen can be used later to produce electrical energy using the fuel cells. Supercapacitor stacks and batteries are used to supply the load during transient conditions and sudden load changes. The load receives power from the hybrid system and from the local grid. Power from the photovoltaic modules and the wind turbines can be used to directly supply the load or to produce hydrogen at low load conditions.

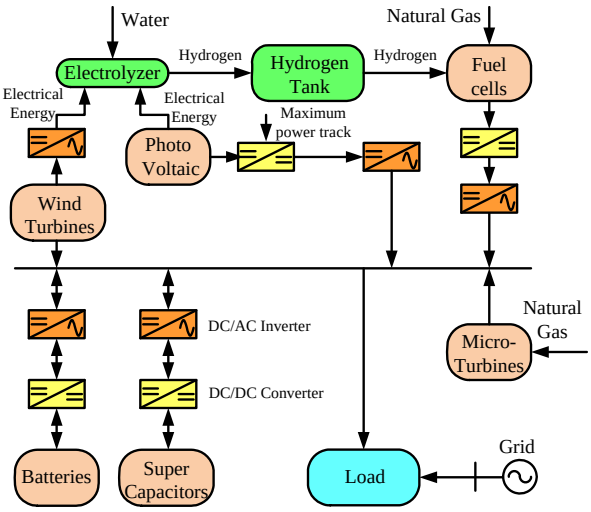

Fig. 1 System under study

ENERGY MANAGEMENT TECHNIQUES

The main objective of the energy management program is to optimally operate the system generators while satisfying the electrical/thermal load demand and minimizing the overall system operational cost. To determine the optimal operational conditions a cost based approach is needed.

Since the system under study is a large scale, non-linear, discrete and non-convex field of application, traditional techniques may lead to a local optimum solution. In addition, computations related to large system are highly memory intensive, therefore traditional techniques are limited to small systems only. Modern methods including genetic algorithms, evolutionary programming, artificial immune system, artificial ant colony, etc have been used to solve different power systems problems [7]-[25]. These new approaches seem to be able to obtain a near optimal solution and to handle systems that are larger than those handled by the classical methods. In the proposed course material, two different artificial intelligence based techniques will be incorporated to determine the near optimal output from each generator in the system that satisfies the electrical and thermal load requirements and minimizes the overall system cost. The first technique is based on evolutionary programming (EP), and the second technique is based on the artificial immune system (AIS).

Evolutionary programming can be traced back to early 1950's when Turing discovered a relationship between machine learning and evolution. During the 1980's, advances of computer technology permitted the use of EP to solve difficult real-world optimization problems [8]-[12]. In recent decades, a new branch of science called AIS was born out of the human immune system. The applications discovered go beyond the area of medicine and biology. With some modifications, AIS is found to be adaptable to many other applications such as optimization, pattern recognition, neural networking, and machine learning problems in different field [14]-[25].

COURSE MATERIAL

To effectively introduce renewable energy management into the Electrical Engineering curriculum, lecture notes, example problems, and group projects, will be developed. In addition, educational experiments/demonstrations and field trips will be arranged. The educational materials will be developed as modules. The design of the modules will be such that all or portions of the modules can be easily integrated not only in the proposed course but also into a variety of courses as appropriate.

EDUCATIONAL MODULES

The following is a list of specific educational modules, which will be developed:

1. Introduction to renewable energy sources: This module will introduce the students to the available renewable energy sources as well as to the sources that are under development.
2. Integration of renewable energy sources with current power system: This module will focus on explaining the limitation, advantages, disadvantages, and necessary equipment needed for each source integration.
3. Renewable energy management: Details of energy management definitions and objectives will be explained in this module.
4. Introduction to cost based approach development: In this module different cost based models with different objective functions and system constraints will be discussed. At the end of the module cost based approach that matches the requirement of the system under study will be developed.
5. Survey of the traditional optimization techniques: This module will give a brief introduction to the available traditional optimization techniques. In addition, it will focus on their applicability and limitation in handling the system under study.
6. Introduction to the artificial intelligence techniques: Advantage of new artificial intelligence based optimization techniques will be discussed.
7. Evolutionary programming based optimization technique: Step by step illustration of how to use evolutionary programming as a powerful tool to solve different optimization problems will be introduced.
8. Artificial immune system based optimization technique: Like the evolutionary programming, the artificial immune system module will show the student the details of using the technique to solve difficult real world optimization problems.
9. Artificial intelligence based renewable energy source management: In this module the evolutionary programming and the artificial immune system will be used to get the near optimal solution of the developed cost based approach in the fourth module. The optimal solution is expected to satisfy the system and the operational constraints and to provide the optimal output from each unit in the system.

10. Data interpretation and recommendations: In the last module the students should be able to decide and recommend the best management technique for the system based on detailed analysis of the obtained data from the previous modules.

Modules 1, 2, 3, 5 and 6 are introductory and therefore do not contain any specific example problems or exercises. The rest of the modules contain an explanation of the specific topic along with comprehensive examples and exercise problems.

CLASS ASSIGNMENTS AND DESIGN PROJECTS

From the first day of the class, students will be divided into groups with two or three students per group. Over the whole semester, individuals of each group will collaborate to solve some special assignment problems. The special problem will be close to the homework problem in nature but might be harder and need some effort. The objective of the special assignment is to promote critical thinking and increase interaction between students. In addition, it will help in enhancing and sustaining intellectual growth among students. Also, two different projects will be assigned to each group. The projects will be based on using evolutionary programming and the artificial immune system to solve small size renewable energy system problems and compare the two techniques in terms of suitability, execution time, and optimal solution. The students will be encouraged to write a technical paper based on their projects. The best four papers will be selected to be presented in the annual University of South Alabama Research Council (USARC) poster exhibition.

EDUCATIONAL EXPERIMENTS/DEMONSTRATIONS AND FIELD TRIPS

Part of the course will involve practical demonstration and site visits. These are as follows: (a) The 5 kW fuel cell generator/load system currently in use in the ECE department will be demonstrated and its functional data will be collected by the students for analysis and evaluation. The fuel cell load is an actual demo-house with one bedroom and a kitchen equipped with electric appliances. A smart control paradigm is used to control the individual appliances and other devices in the house. The students will be made familiar with the control architecture associated with the system. (b) A functional solar cell unit will be studied by the students. Data acquisition techniques using virtual instrumentation in association with the solar cell system will be demonstrated. (c) At least one field trip will be arranged to the 8MW hydro station located in Gantt, Alabama. (d) The students will be taken on a field trip to a nearby wind generating station.

CONCLUSIONS

In this paper, strategies of developing and teaching a multi-disciplinary renewable energy management based course are introduced. The focus of the course is to educate and prepare not only the electrical and the computer engineering students but also students of other engineering disciplines. This will enable them to handle and manage different grid connected renewable energy sources. The management techniques will be based on two different artificial intelligence techniques, namely evolutionary programming and artificial immune system. The course is expected to expose students to different tools and techniques that will help in producing future engineers that are capable of addressing energy related issues that are anticipated in the forthcoming future. The course will be a multidisciplinary in nature, which will help in attracting students of other disciplines in addition to engineers from the local industry.

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BIOGRAPHIES

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