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Monitoring and Control by Virtual Tools of an Educational Renewable Energy System

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Abstract

The scope of the present paper is to present the architecture and design of an effective tool useful for monitoring, maintenance and training of specialists in the field of photovoltaic renewable energy

Among renewable energy resources, solar energy represents an easy to use, accessible and green source of energy. An important goal is the efficient use of solar energy which can only be achieved by the knowledge of solar datum and equipment characteristics from a studied area. Based on this idea, the paper presents a concept of virtual tools developed on web technologies and virtual instrumentation for monitoring and control of solar renewable energy. These tools are mainly designed as a base for a virtual laboratory that can be used for the study of photovoltaic and thermal solar energy parameters, representing, by didactical point of view, a handful way for students to study the phenomenology and also a training tool for specialists in the field of solar photovoltaic energy.

1. Introduction

The recent growth of renewable energy usage as a result of installation of more and more generating units involves preoccupations concerning their monitoring and maintenance. This leads to the conceiving of new and effective tools for monitoring and control regarding these systems but also to the training of specialists in the field of renewable energy systems.

One of the renewable energies on which nowadays scientists are focused is represented by the solar energy and its uses. An important point is focused on the efficient use of system based on solar energy, which involves the knowledge of solar data and equipment characteristics from a studied area. Also this is important by didactical point of view requiring students to access real data and concentrate on phenomenology using adequate tools. Authors of this paper have developed a tool suitable for research and learning.

This tool was designed from the perspective and the importance represented nowadays by renewable energy technologies. One can see the important benefits of renewable energy compared to those of conventional energy sources. Many of them are significant related to the environmental benefits obtained, such as [1]:
- no production of air pollution or hazardous waste;
- clean and inexhaustible source of energy;
- don't require liquid or gaseous fuels to be transported or combusted;
- PV sources can generate power in all weather and climates since their modules resist under the worse environmental conditions;
- PV systems have clean, safe, reliable and quiet operation;
- easy maintenance;
- energy security and efficiency;
- installed PV system generate power continuously with minimal operating costs;
- PV modules and battery bank are modular so you can double or increase the PV systems anytime;
- reduction of dependence on foreign and/or decentralized sources of energy;
- PV systems are usually placed close to where the electricity is used, so they require much shorter power distribution lines than those needed to bring power in from the utility grid;
- consumers can produce the energy they need within their own borders;
- operating time of over 30 years;
- reduction of utility energy bills;
- operates reliably for long periods of time with virtually no maintenance;
- power from the PV system is transferred to the utility company. The owner of any grid-connected PV system can buy and sell electricity to the utility company.

2. Virtual Tools Specifications

One of the main purposes of our work is to develop a system usable for monitoring, technical study on-site and for on-line distance learning. The main goal of the system is to provide an access to a

Keywords: *renewable energy resources, educational intranet laboratory*

photovoltaic production unit, primarily for monitoring or for control of primary energy source parameters when used for study. All these are including the permanent access to current data but also to the recorded ones too. When the photovoltaic unit is used for experimental and learning purposes the system is designed to provide a way to a good understanding of physical phenomena and of measured parameters related to photovoltaic systems such as:

- measurement of irradiance, open circuit voltage and short-circuit current from photovoltaic cells,
- study of power, temperature, voltage and current characteristics from the power cells or modules,
- study of serial and parallel connection of solar modules and the partial shading of a photovoltaic generator,
- study of loads directly fed or fed by stored power studied on-site on the workstation.[4]

The system can be used for study of theoretical models, but also for study of above parameters influence and comparisons to real models. Obviously, when the control function is activated, the studies on real models can be performed when the solar radiation is available or by using an artificial source of lighting radiation.

The system was conceived to perform studies using existing data but also data preset by user. In the case of on-line study, data history can be used for the study of available solar radiation during different periods of time. The analysis of registered data can be performed in off-line study.

The available physicals models can be tested in different configurations at different parameters (e.g. solar photovoltaic cells of different parameters in series or parallel connections).

3. System Architecture

Figure 1 shows the block diagram of the e-learning proposed system. The system is structured

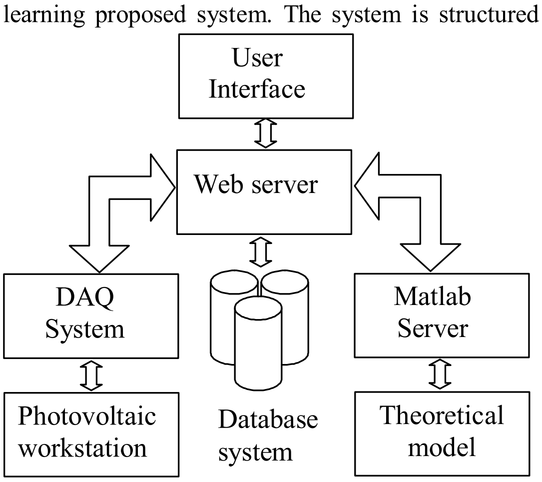

Figure 1. Architecture of the system

on 3 components:

- experimental workstation with an DAQ module;
- the module for study of theoretical models;
- web based application with database;

The experimental workstation for the study of photovoltaic solar energy is represented by a basic Lucas-Nulle workstation extended with a data acquisition module implemented with a computer equipped with PCL711 DAQ board [3]. Data obtained from DAQ board are pre-processed and sent to the upper levels of the application by a software component developed in LabWindows/CVI.

The workstation (Figure 2) contains two types of solar energy converters: solar cells and photovoltaic solar panel.

Solar cells are represented by integrated SO 32107 M, Lucas-Nulle modules. There are two types of solar cells: 2 modules of 6 Volts which can be connected serial or parallel configurations, and a 3 Volts module. [4]

Solar panel is of ET-M53620 type characterized by the following parameters:

- Peak power (Pmax) 20W;
- Maximum power point voltage (Vmpp) 17.82V;
- Maximum power point current (Impp) 1.15A;
- Open circuit voltage (Voc) 21.96V;
- Short circuit current (Isc) 1.27A.

Energy conversion at a level usable by consumers is realised with two 12V DC-230VAC-50 Hz-150W inverters supplied by two solar charge controller SOLSUM 5.6 and SOLAR 18122. Supplemental energy is stored in a 12V accumulator [5].

For testing purposes are used 12V DC consumers and 220V AC consumers.

DC consumers are: DC motor of 3.3W, halogen lamp 12V/5W, a LED 20mA and a 12V socket for connecting other 12V DC consumers. The two inverters offers the possibility to connect different types of AC consumers and for testing purposes is used a 230V/150W halogen LEDs lamp.

Figure 2. Photovoltaic laboratory workstation

For time analysis of solar energy availability a MacSolar device from Solarc is used [3].

4. System Implementation

An important part of the system is represented by software development. Software development is based on:

- data acquisition and conditioning;
- data storage and retrieval;
- remote access by web application;
- simulation models.

The implementation of this software package is conceived as follows:

A. Photovoltaic Workstation DAQ and Conditioning System

The photovoltaic workstation DAQ and conditioning system is implemented by a PCL711 DAQ board [2] and a software application developed in LabWindows/CVI environment. The application sends the data to a database or to the web application if an experimenter requests that. Data flow diagram of this module is shown in Figure 3.

B. Data Storage and Retrieval

The discontinuous availability of primary energy source for experiments requires data storage. By using data storage module the data can be studied on various periods of time. The web application is implemented in this experimental phase using MySql database management system for data storage and web communication. The main data source is the DAQ module and the beneficiaries are the database and web application.

C. Remote Access by Web Application

The access to the virtual laboratory is allowed with username and password identification. Once the user is logged-in, it can perform a new experiment or an existing one. In case of a new experiment, the photovoltaic workstation users have to make a system reservation. The actual modules don't allow a simultaneous access for more users. In the future, it is intended a development of a system which allows parallel experiments by multiplexing user access using a faster DAQ architecture.

The complete state flow diagram of web application modules related to the e-learning system is presented in Figure 4.

For web application support we are using the Apache sever running on Linux machine, CGI applications written in C/C++ language and PHP applications for web interface [6], [8], [10].

D. Simulation Models

The simulation of photovoltaic system requires complex mathematical models implemented and validated in a convenient way with Matlab. The simulation results are available to the web system by using Matlab Server application. The advantage of

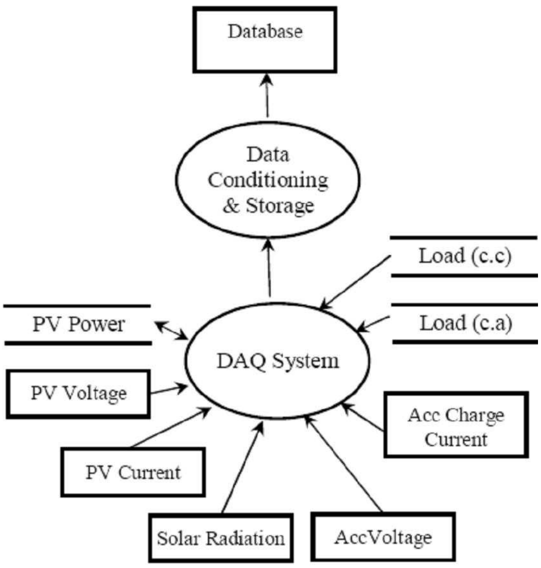

Figure 3. Data flow diagram of the DAQ System.

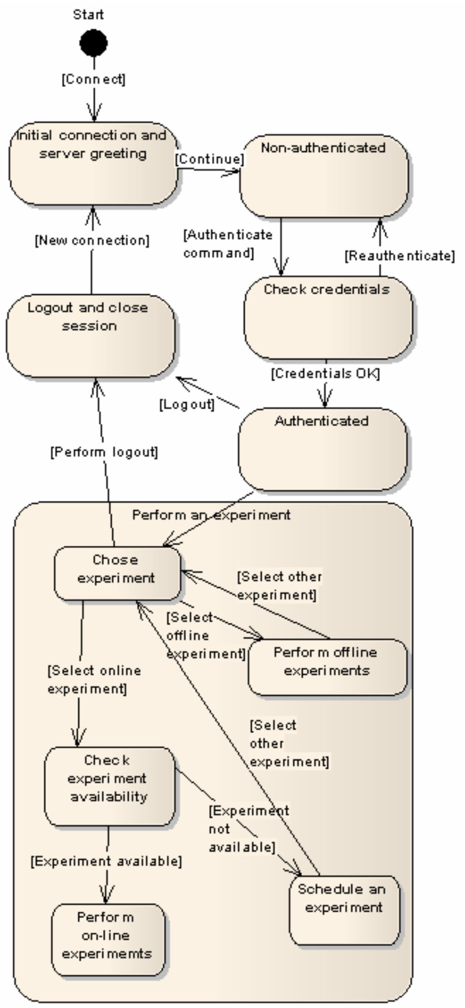

Figure 4. State and flow diagram of the web application modules

such implementation is an easy way to simulate and validate existing and new models.

5. Case Study

As follows, it will be illustrated the system functioning as virtual laboratory. The use of system is possible only by the authorized persons. A system user will access the intranet page for laboratory access and provide his credentials as shown in Figure 5.

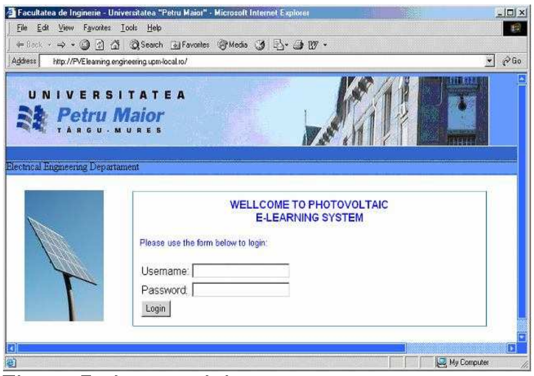

Figure 5. Intranet laboratory access page.

After authentication users can chose the activities to be performed from a list. For example, the user chooses a new on-line handling of the photovoltaic system. From an available list, the user will choose the configuration he intends to work with, for example Analisys of Power and Temperature Characteristics at MPP (Maximum Power Point) for Photovoltaic Solar Cells as shown in Figure 6.

The system tests if any other handling is currently in progress by other user and offers the possibility to program the experiment for a certain hour or to access the workstation, if it’s available. By accessing the above mentioned experiment, the user has to select the consumer charge level and the upper and lower level of the solar radiation.

The laboratory workstation automatically provides voltage and current measurements for

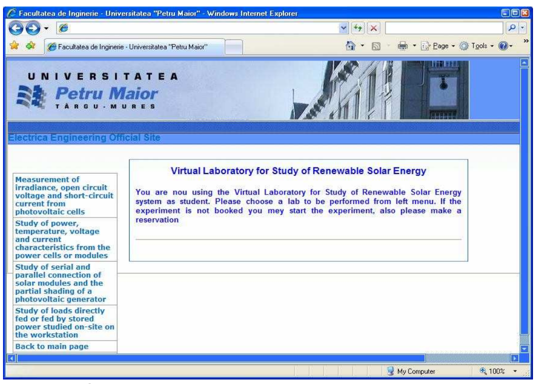

Figure 6. Intranet laboratory available handling activity list.

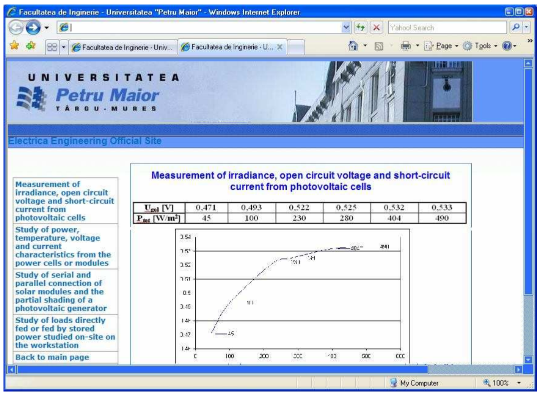

Figure 7. Intranet laboratory analysis and results page.

different values of solar radiation.

At the end of the experiment the system displays the graphic characteristics. For example, considering a resistive consumer of 3Ohm the system displays a characteristic as shown in Figure 7.

6. Conclusions and Future Work

The present paper presents a system designed for monitoring and remote control of a solar photovoltaic system with modern web-based tools.

The system was designed also to accommodate the function of a virtual laboratory for the study of a renewable solar energy system. The basic idea of the implemented system is to allow several users to perform analysis or common laboratory experiments during their studying courses like Renewable Energy Sources and also to allow them to plan their own working time.

To facilitate access to laboratory experiments, the usage of web technologies in the development of the application was proposed. In order to perform the experiments on real laboratory workstations, the conception of some modules to provide the interfacing and assurance of access through web interfaces was necessary.

Considering that the study consists in the data analysis and in their processing, the databases for stored data obtained from the measurements in the experiments or any other information necessary for a good functioning of the application were used. An important facility is offered by the possibility of a later access to previously recorded information about the experiments, which is the opportunity of performing off-line analysis.

A few types of technical and scientific analysis that can be performed on the prototype photovoltaic workstation are: measurement of irradiance, open circuit voltage and short-circuit current from photovoltaic cells, study of power, temperature, voltage and current characteristics from the power cells or modules, study of serial and parallel connection of solar modules and the partial shading of a photovoltaic generator, study of loads directly fed or fed by stored power.

The important side of laboratory experiments is the data availability when multiple devices are available and distributed. Also cannot be neglected the necessity of many applications to have data availability over local, wide or Internet. As we have developed this application with the possibility of transmitting data through local networks for solar panel systems we hope to extend this application to hybrid systems in order to control and monitor those systems from distance.

Due to the modular development and open architecture of the application new facilities and new activities can be added.

Also by adding new modules and interfacing devices the existing system can be extended to other workstations and courses.

As a near future work we intend to extend this application to a hybrid system composed by solar panels, wind turbines and perhaps some fuel cells.

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