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EDUCATION IN SOLAR ENERGY AT THE "POLITEHNICA" UNIVERSITY OF TIMIŞOARA

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Abstract. Following recent economic trends in the field of solar energy and an increasing need for specialists, a Master Degree has been introduced at the "Politehnica" University of Timişoara last year. The Curriculum is applications oriented and covers both PV and thermal aspects. In this paper, we present some topics that are intended for laboratory classes: thermal circuits in a Solar House, which can also be used for demonstration.

***Keywords*:** Solar Energy, Education, Curriculum, Collectors, Thermal Circuits.

Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Material and methods

Forecasts indicate that fossil and nuclear resources will be exhausted in the future, so that renewable resources will replace them in the production of energy. Among renewable resources, solar technology plays an important role. Grid connected PV systems had the most important growth rate in 2005 with respect to 2004 (55%), followed by the rest of solar systems (24%). The total surface of thermal solar collectors in the world has been of 164 million m^2 at the end of 2004. The capacity of solar thermal systems in the world has been of 88GW in 2007 [COMMISARIAT À L'ÉNERGIE ATOMIQUE, 2008].

The cost of PV collectors dropped by 9% in the last year; the cost of solar panels decreased to about 4 Euro/W.A 6.634GWp capacity of PV solar systems existed at the end of 2006.

It is believed that the worldwide market of solar technology will reach an amount between 18.6 and 31.5 billion dollars in 2001. The development of the PV industry beneficiates, especially in Europe, from the awareness of political actors of the necessity of increasing production in order to reduce costs by financial incentives aimed to producers [SANDÉN B. A, 2005].

Investments in Solar Energy education have followed an evolution in opposition with the international price of oil: a rapid growth in the seventies, followed by stagnation in the eighties [YOGI GOSWAMI D., 2001]. However, in the present, after two decades, several new issues such as shortage of conventional resources, carbon emissions producing global greenhouse effect and ecological implications determined a rise of public interest for alternative sources of energy in general and for solar energy in particular.

Many electronic resources that can be used for education in solar technology exist on the Internet [YOGI GOSWAMI D., 2001]. However, it seems that higher education in the field is less developed than education aimed to lower levels and general public [HASNAIN S. M., ALAWAJI S. H., ELANI U. A., 1998].

A certain number of universities and other educational institutions develop programs in Solar Energy or introduce aspects related to it in the curricula of various specializations.

For the academic community, spreading of educational experience gained is important. For example, the particular way of introducing daily solar lighting for students in Architecture is presented in [MANSY K., A, 2004] and a demonstrative, simplified procedure for the construction and measure of nanocrystalline solar cells is reported in [SMESTAD G. P., 1998].

An interdisciplinary two-year Master Degree in Solar Energy has been started at the "Politehnica" University of Timişoara in 2009. The field requires a practical training of students so that the educational activity is mainly application oriented.

We present below the structure of the

Program and, as an example, the laboratory work for students devised around the "Solar House", a building that has been refurbished and provided with modern equipment in view of a convenient development of the educational process. Both a PV system and thermal equipment have been purchased. However we will concentrate here on the education on thermal applications of Solar Energy.

Presentation of the Master program

The Master Program in Solar Energy has been devised in the context of an important public funding aimed to resume research and education in solar energy at the "Politehnica" University of Timişoara.

It is coordinated by the Department of Physical Foundations of Engineering (PFE) and the multidisciplinary character is ensured by the participation of the following departments from various faculties of the University: Automation and Applied Informatics, Power Engineering, Measurements and Optical Electronics, Installations for Civil Engineering and Architecture. The PFE Department has a long history in research on solar applications, started in 1976 [LUMINOSU I., DE SABATA C., DE SABATA A., 2010].

The opportunity of organizing the master program stems from the fact that economic agents and individuals are determined to use alternative energy sources, motivated by the reasons presented above. Among these sources, solar energy is non polluting, free and available in large quantities and may be used in various applications, such as heating, climatization, production of electricity, distillation etc.

The mission of the program is to prepare human resources able to respond to European challenges regarding the energy of the future.

The program is supposed to educate students in view of creation of three kinds of competencies:

1. Cognitive competencies relying on understanding of the positive impact of unconventional sources of energy on the quality of life and ambient, understanding and interpretation of physical phenomena involved in conversion of solar energy into other forms of energy and on knowledge of standards in solar buildings;

2. Applicative and practical competencies based on knowledge of thermal and PV energy chains, capacity of innovation and evaluation of new PV and thermal systems, expertise in design of automation systems for solar installations and experience in maintenance of solar installations;

3. Communication and relational competencies based on capacities of dissemination of results in solar energy conversion, capacity of distribution of solar products and ability to attract funding for solar energy research and industry.

The curriculum comprises mandatory and optional disciplines. The options allow for choosing a thermal or a PV specialization. Pedagogy courses, intended for students interested in following a teaching carrier, are offered each semester. The curriculum is synthesized in Table 1.

The following courses provide formal and fundamental knowledge: *Physics of Solar Energy*, *Renewable Energy* and *Data Acquisition and Processing.*

Specialized and application oriented knowledge is provided by the courses on: *Thermal – Solar Conversion*, *PV Conversion*, *Thermal Solar Systems*, *PV Systems*, *Optical Electronics* and *Automation*.

The need for an ecological attitude as a new paradigm for the European specialist is covered in the courses on *Equipment for Solar Buildings* and *Solar Architecture.*

The course on *Management of Solar Buildings* contributes to the enhancement of management capabilities of students in the field of new energy sources.

The future of the program is ensured by the evolution of the energy field on national, European and worldwide levels.

The goals that have determined the structure of the master program are: production of solar equipment provided with automation; creation of new materials with superior properties; raise of buildings with high energy efficiency; creation and design of new solar installations with improved efficiency; expertise in solar systems; maintenance of solar installations in working conditions; realization of feasibility studies; and dissemination of knowledge and education.

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Table 1.

Discipline	Sem.	No. of hours	Credit points	
Physics of Solar Energy	1	56	8	
Renewable Energy	1	42	7	
Data Acquisition and Processing	1	42	8	
a) Thermal – Solar Conversion b) PV Conversion	1	42	7	Opt.
PV Systems (1)	2	42	7	
Thermal Systems (1)	2	42	8	
Optical Electronics	2	42	7	
a) Automation of PV Systems b) Automation of Thermal Syst.	2	42	8	Opt.
PV Systems (2)	3	42	8	
Thermal Systems (2)	3	42	7	
Equipment for Solar Buildings	3	42	7	
a)Management of Solar Buildings b) Solar Architecture	3	42	7	Opt.
Practical Training and Research	4	98	15	
Diploma Preparation	4	98	15	

The "Solar House" and Thermal Circuits

Solar houses are equipped with thermal solar systems that accomplish certain functionalities like climatization and heating water. Unfortunately, best solar radiation and highest need for heat are not simultaneous events. Practice has shown that the energy chain in a Solar House should have standard elements: solar collectors, pipes, boilers, splitters and radiators.

The Solar House building is presented in *Figure 1*. The walls are made of bricks and thermally insulated with a polystyrene sheet. The concrete ceiling is hydro insulated. The building has two rooms, an entrance hall and a corridor. The windows and doors are built from materials that provide a thermal insulation.

Figure 1. The Solar House.

The collectors are placed on the ground, on a terrace situated in front of the southern wall and on the roof of a neighbor building and a parabolic concentrator is mounted on the terrace of the Solar House.

The building is equipped with three thermal solar circuits, each composed of solar collectors for conversion of solar energy into thermal energy, insulated pipes for heat transportation and boilers for accumulation and storage of thermal energy as heat. The storage material for heat is water. The thermal insulation is realized with polyurethane foam.

The collectors are of "Solaren" type with thermal tubes. These collectors are fabricated in two different variants: pressurized, with pumps for the circulation of the working agent and without use of pressure, such that the working agent circulates by thermosyphon. The greenhouse effect is realized by means of Jena glass plates. The splitters are made of silvered copper and soldered with brass and the supporting frame is in stainless steel. The "Solaren" collectors can work under negative temperature conditions and are resistant to corrosion.

The installations are equipped with microcontrollers, Seebeck effect based thermometers, pressure gauges, expansion pots for pressure regulation and optionally with flow rate gauges. The collecting field consists of seven panels with a variable number of thermal tubes, between 12 and 30. The surface of each collector is in between 1.8 and 4.5 m^2.

The boilers have volumes between 150 and 200 l and are equipped with serpentine heat exchangers, valves and magnesium electrodes in order to prevent corrosion caused by the contact potential between metals. The power takes values between 1800 and 4500 W depending on the collecting area of the panels. With such systems, an annual economy of natural gas between 1440 and 2400 m^3 may be obtained.

The three thermal circuits of the Solar House are the following.

Circuit 1: 17.1 m^3 collecting area; three pressurized panels, connected in parallel, each comprising 12, 18 or 24 tubes; the collectors are oriented to south and tilted by 45 deg; two boilers with volumes 200 l and 500 l respectively; the extra heat is transferred to a tank situated outside the building.

Circuit 2: 3.6 m^2 collecting area; one panel equipped with 24 tubes and with variable orientation and tilt; one boiler with a 200 l volume.

Circuit 3 : 3 m^2 collecting area; one panel not pressurized, with natural fluid circulation, provided with 24 tubes, oriented to south and tilted by 45 deg.

Practical Work

a) Circuit 1

The aim is to determine the variation of efficiency versus time. The boiler filled with cold water is connected to collectors. Then, every five minutes the following quantities are measured: temperature of water in the boiler T_B, temperature of water in the input pipe of the boiler $T_{in,B}$, temperature of water in the pipe at the output of the boiler $T_{out,B}$, temperature of the ambient T_a, the flow rate of the heating water $\dot{m}$, intensity of global solar radiation on a horizontal surface G. It is admitted that the temperature of the pipes that circulate the working agent is approximately constant for small time intervals.

The efficiency of the boiler in the heat accumulation process is:

$$\eta_{B_i} = \frac{Mc\left(T_{B_i} - T_{B_{i-1}}\right)}{\dot{m}c\left(T_{out,C_i} - T_{in,C_i}\right)\Delta\tau} \qquad (1)$$

where: c is the specific heat for water; $\Delta\tau$ is the time interval (5 min.), the subscript C denotes the collector, i is the sequency index.

In order to calculate the efficiency of the collecting system, the heat lost by the pipes is neglected. The temperature at the collector input is taken to be equal to the temperature at the boiler output $T_{out,B} = T_{in,C}$ and the temperature at the collector output is considered equal to the temperature at the boiler input $T_{out,C} = T_{in,B}$.

The efficiency of the collecting system is:

$$\eta_{C_i} = \frac{\dot{m}c\left(T_{out,C_i} - T_{in,C_i}\right)\Delta\tau}{A_C G_{C_i}\Delta\tau} = \frac{\dot{m}c\left(T_{out,C_i} - T_{in,C_i}\right)}{A_C G_{C_i}} \qquad (2)$$

and the efficiency of the installation is:

$$\eta_{inst} = \eta_C \eta_B = \frac{Mc\left(T_{B_i} - T_{B_{i-1}}\right)}{A_C G_{C_i}\Delta\tau} \qquad (3)$$

Finally, the efficiencies are represented versus time $\eta = f(\tau)$.

b) Circuit 2.

The purpose is to determine the influence of orientation on the collector efficiency. The orientation of the collecting surface is characterized by the azimuth γ and the tilt angle with respect to the horizontal plane s.

The azimuth of the panel oriented to south is zero (γ=0). The panel is oriented to east by 15 deg and then by 30 deg before noon and by 15 deg and 30 deg to west in the afternoon. For each azimuth, four tilt angles are choosen s = 15; 30; 45; 60 deg. The water in the boiler is circulated continuously, so that its temperature remains constant. For each pair of angles γ and s the following quantities are measured G, T_a, $T_{in,C}$, $T_{out,C}$, $\dot{m}$. The efficiency of the collector is calculated with (2).

Finally, the efficiencies are represented versus collectors orientation and tilt: $\eta = f(s, \gamma)$.

c) Circuit 3.

The aim is to determine the time variation of the efficiency of an unpressurized collector.

The tank is filled with cold water and the temperature of the water in the tank, the ambient temperature and the irradiance in the collector plane are measured for an hour, every 5 minutes. The efficiency is calculated with the following equation

$$\eta_{inst} = \frac{Mc\left(T_{rez_i} - T_{rez_{i-1}}\right)}{A_C G_{C_i} \Delta\tau} \qquad (4)$$

Based on experimental data, the time variation of the efficiency is represented $\eta_{inst} = f(\tau)$.

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions

The evolution of the problem of energy in the world has determined a rise of the general interest in renewable resources in general and in solar energy in particular.

The development of new applications of solar energy technology requires well trained specialists in the field. A two-year master degree program in solar energy has been started at the "Politehnica" University of Timişoara last year. The curriculum has been devised in function of the competencies the graduates have to acquire. The educational activity is mainly applications oriented.

As a specific example, we have presented some laboratory activities devised for students. The equipment used is quite complex and expensive, but the expected results in terms of information, formation and demonstration motivate the investments.

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