UDC 620.91

DISTANCE LEARNING LABORATORY BASED ON EXISTING HYBRID INSTALLATION WITH RENEWABLE ENERGY SOURCES

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The examples of real hybrid systems consist of renewable energy sources used to provide hot water and central heat for buildings have been presented. These installations are equipped with advanced control system which allows to users to balance energy and costs. It is possible to remote control the installation at the four different access levels and control temporary parameters in real time over the Internet. These possibilities gave us the idea of using such instrumented installations as “distance-learning laboratories”. They are already used by students from cooperating universities who are interested in renewable energy.

Key words: solar thermal energy, control system, renewable energy sources.

ЛАБОРАТОРІЯ ДИСТАНЦІЙНОГО НАВЧАННЯ ІЗ ЗАСТОСУВАННЯМ ГІБРИДНОЇ УСТАНОВКИ, ЩО ВИКОРИСТОВУЄ РІЗНІ ВІДНОВЛЮВАНІ ДЖЕРЕЛА ЕНЕРГІЇ

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Наведено приклади реальних гібридних систем, що використовують відновлювані джерела енергії для забезпечення будинків опаленням та гарячою водою. Ці установки обладнані інтелектуальною системою контролю, яка дозволяє користувачам здійснювати баланс енергії та затрат. Систему можна контролювати на чотирьох рівнях доступу та змінювати параметри системи через мережу Internet.Ці можливості дозволяють використовувати таку установку як лабораторію для дистанційного навчання. Такі лабораторії вже використовуються студентами, які зацікавлені у відновлюваній енергетиці, у рамках співпраці між університетами,.

Ключові слова:сонячна термальна енергія, система контролю, відновлювані джерела енергії.

PROBLEM STATEMENT. The observed technological prices of conventional energy carriers have gone up significantly over the last years. In addition, the resources are becoming depleted and their utilization for the production of electric and thermal power and for the production of fuels is burdening the natural environment. This has given rise to an intensive search, both globally and in Europe, for a way of using renewable resources as a source of energy and chemical products.

These activities are particularly noticeable in the countries of the European Union (EU). In view of the need to protect climate, in 2008 the 27 EU-countries agreed to increase the actual utilization of renewable energy resources (RES) so as in 2020 no less than 20% of total energy consumption will come from renewable sources. Some Middle and Eastern European countries, including Poland, negotiated a smaller share; for Poland it is a 15% share of renewable energy in the overall energy balance until the end of 2020. Germany has a legal regulation [1] saying that beginning from 2020 all newly constructed buildings must use a specified percentage of energy from renewable resources. That share in the general energy balance ranges from 15% to 50%.

One of the known ways of obtaining thermal energy for central heating of houses [2, 3] and obtaining domestic hot water [4] are solar collectors – flat or vacuum. The so called 'solar constant' determines the density of energy stream directed from the sun to the globe and equals approx. 1367 W/m2. After taking into account absorption and reflection of a part of that stream in the atmosphere [5], only about 1000 W/m2 reach the surface of the Earth. Throughout the year the Earth receives, depending on the location, between 800 kWh/m2 and 2200 kWh/m2 energy from the sun. As a result, intensive research and development is going on in many countries to improve the efficiency of solar energy acquisition and conversion, as well as enhance saving and rational use of that energy [6, 7].

As a result of cooperation between Section of Fundamental Processes and Environmental Protection Devices of the Cracow University of Technology and installation companies in the region of Małoposka, a number of innovative installations utilising renewable energy sources have been made in the recent years [8], which are used both for practical and research purposes. Components of those installation include: solar collectors, heat pumps and biomass boilers. The installations are generally equipped with a control system and an energy and cost balancing system, making it possible to monitor the operation of each installation in real time [9] online. The system also features remote control of such installations.

EXPERIMENTAL PART AND RESULTS OBTAINED. *Examples of installations serving practical and research functions.*

Students' access to specialised laboratories and ability to directly watch the tasks performed are important conditions of education. The potential of control and balancing system in RES installations has become a motivation to attempt to make those installations part of the educational process in the form of distance laboratories. Out of the four installation examples shown below the operation of three can be observed by the students of the Cracow University of Technology, the AGH University of Science and Technology in Cracow and the Poltava State Agrarian Academy in Ukraine. These are:

1) A hybrid installation with RES in a summer cottage located about 50 km off Cracow (Fig. 1). The house with the square area of about 100 sq.m. is fitted with a battery of flat solar collectors with the square area of about 14 sq.m., an air-to-water heat pump, a biomass boiler with 12 kW power output and an electric boiler. The installation has been in operation since 2008 without a breakdown.

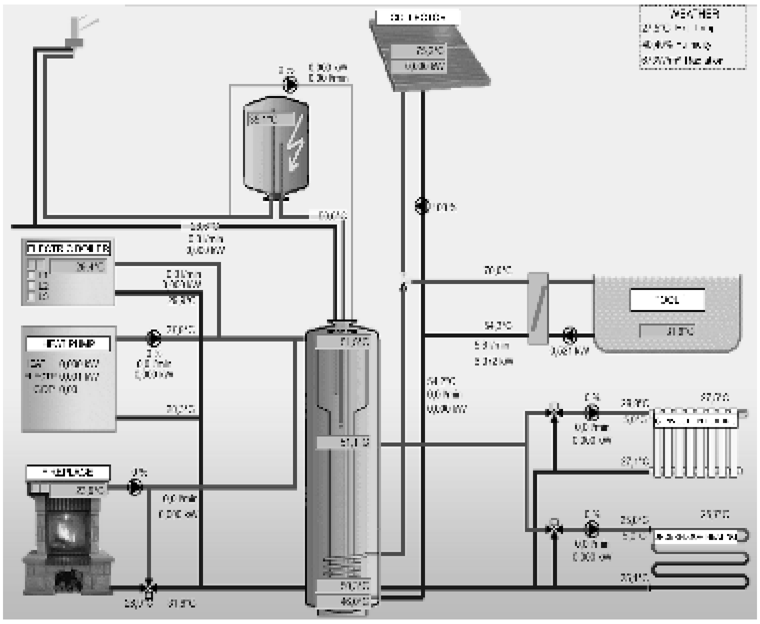

Figure 1 – Flow chart and operational parameters of the installation described in Section 1, page 2, as on 7 August 2012 at 2.35 PM

2) Installation with three different types of solar collectors operating at the Cracow University of Technology used for surveying the efficiency of flat and vacuum collectors in real-life conditions (Fig. 2). It is also equipped with a demonstration photovoltaic panel. The system has been in operation since 2010.

3) Hybrid installation with RES in a habitable and service building in Batowice (9 km off Krakow city centre) with the square area of 450 sq.m. fitted with a battery of five vacuum collectors 20 pipes each, a liquid-to-liquid heat pump with the power output of 17 kW with vertical probes, a condensation gas boiler with power output 21 kW and a biomass boiler with the power output of 24 kW. The installation was put into operation in October 2011.

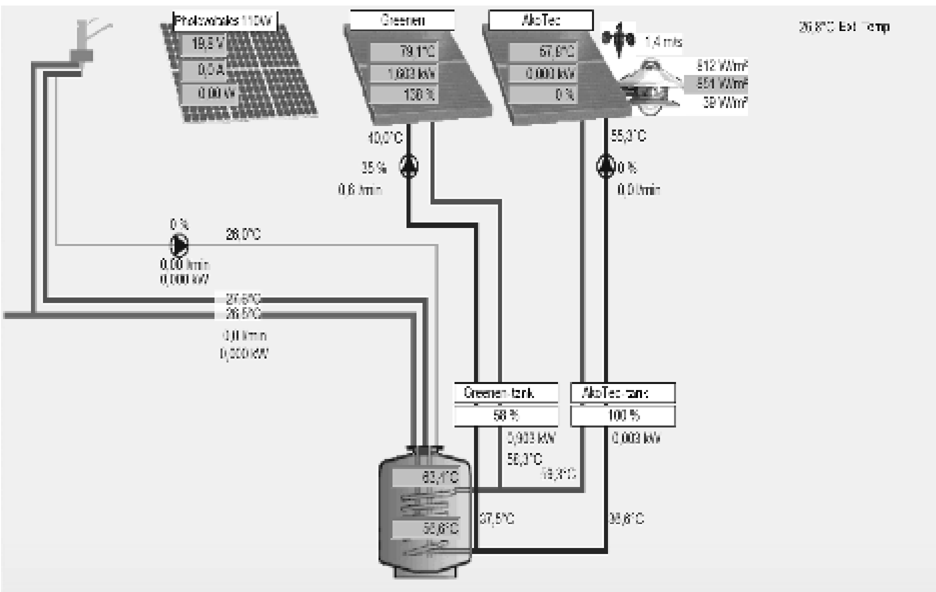

Figure 2 – Flow chart and operational parameters of the installation described in Section 2, page 2, as on 7 August 2012 at 11.56 AM

4) Installation with solar collectors and an air heat pump located at a distance of about 1200 km from Cracow, in Poltava in Ukraine (Fig. 3). It is a research and educational laboratory for surveying various types of solar collectors equipped with an air-to-water heat pump with the nominal thermal power output of 3.5 kW. The installation was modernized, extended and fitted with DigiENERGY control system in September 2011.

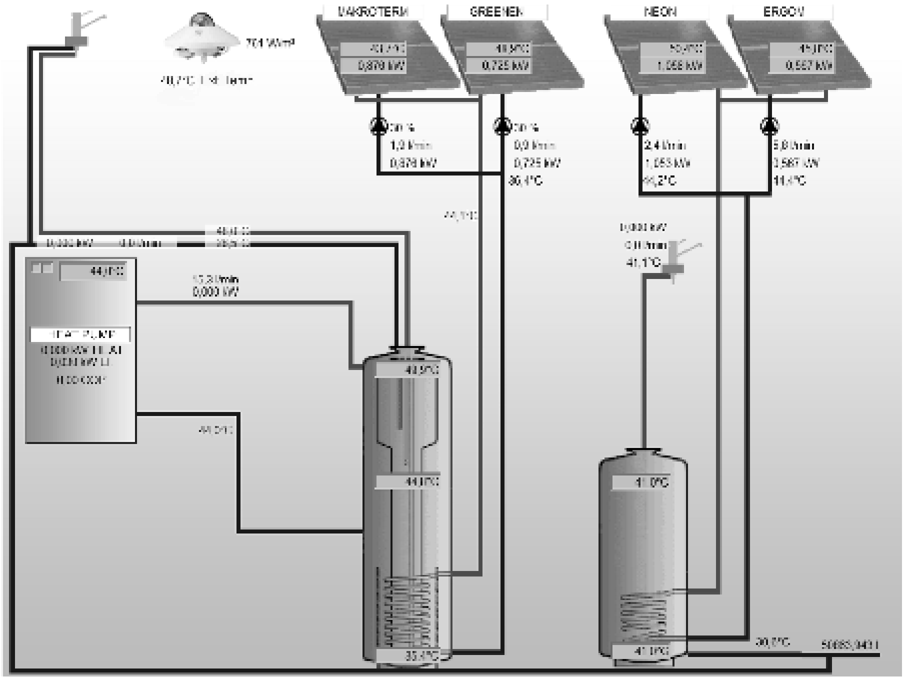

Figure 3 – Flow chart and operational parameters of the installation described in Section 4, page 3, as on 7 August 2012 at 1.01 PM

Control, energy and cost balancing potentials illustrated with the DigiENERGY system installed in hybrid installations.

Solar collectors:

– Control and independent balancing of two fields of collectors, e.g. collectors oriented eastwards and westwards or collectors of two different types, such as flat and vacuum, operating parallelly to each other. Control and balancing of one field of collectors may be replaced by a different device.

– Control of the flow of solar medium is based on a preset difference of temperatures ΔT at outlet and inlet to collector.

– Circulating pump flow rate is adjusted smoothly within a range of 35–100 % of the nominal flow rate. This is done by adjusting the rotation frequency of the pump in the PWM system (Pulse Width Modulation). The system operates by changing the width of modulation with a fixed frequency for the signal passed to the pump.

– In solar cycles it is possible to measure momentary power and the amount of energy delivered within a preset time range. Temperature difference is measured with the same PT–1000 sensors that are used for the control of circulation in the collector.

Boiler for solid fuels, e.g. firewood:

– Boiler's heating cycle is controlled by turning on the circulating pump when temperature of heat transporting medium exceeds the minimum temperature, which should be higher than the temperature of dew point on the wall of combustion chamber (approx. 40–50 °C) and higher than current water temperature in heat accumulator.

– The stream of the flowing heat medium can be controlled by using variable pump outflow in the PWM system or by the grade of opening of the three-way mixing valve at circuit return to boiler.

Other devices for the production of thermal energy which can be installed as part of hybrid installations (heat pumps, gas boilers, oil boilers):

– Devices such as heat pumps, gas boilers and oil boilers are controlled so as to ensure that energy they produce is equal to momentary demand for heat.

– Controlling those devices through a system ensures their start-up and shut-down are fast and smooth.

– Operational parameters of those devices are adjusted to external temperature and its change trend.

– Heating power can be adjusted smoothly or at increments (2 power grades).

How the students of RES-related or associated subjects can use any "distance laboratory" provided they have the basic access code.

Information about the current status of installations and historical data from previous heating seasons are made available online via web servers. After entering the basic access codes students are able to:

− Analyse actual insulation and sunshine duration, as well as solar radiation in locations of the selected installations.

− Compare the efficiency of various types of solar collectors in the function of a direct and dispersed solar radiation flow falling on their surface, operating in real-life conditions.

− Analyse how the speed of flow of the medium affects the efficiency of solar collectors in specific weather conditions.

− Compare energy yields from of various types of solar collectors (flat collectors, vacuum-pipe collectors, heat-pipe collectors, U–pipe or direct-flow collectors).

− Analyse energy and cost efficiency of other thermal energy producing devices forming part of hybrid installations, such as heat pumps and various types of boilers, in arbitrarily selected time range.

− Balance the amount of thermal energy acquired by the whole hybrid installation in an arbitrarily selected time range and confront it with the actual consumption.

− Study thermal losses in accumulators – heat exchangers, which affect thermal energy storage savings.

− Appraise the cost of producing thermal power from particular sources and from the whole installation, taking into account the cost of electricity consumed by circulating pumps and other accompanying equipment.

− Create mathematical models for the process of thermal power generation and consumption, and confront the results of those models with actual results.

− Compare energy, environmental and economic efficiencies of various energy sources used in hybrid installations.

− Estimate the payback period and cost-effectiveness of hybrid heating installations with renewable energy sources.

Examples of the functions of the DigiENERGY control system.

The discussed control system offers a number of useful functions, one of them being Meter Readings which allows a user to follow current thermal and electric powers at metered points of installations (Fig. 4).

	current	counter now	01.01.2011	31.12.2011	=	price / unit	bil
POOL PUMP	0,422 kW	1405,250 kWh	289,142 kWh	1352,403 kWh	1063,301 kWh	45,000 gr/kWh	481,20 PLN
CONTROL ELECTR.	0,076 kW	1239,780 kWh	425,124 kWh	1222,235 kWh	797,111 kWh	45,000 gr/kWh	350,00 PLN
HEAT PUMP ELECTR.	[illegible]	744,735 kWh	0,000 kWh	742,810 kWh	742,810 kWh	20,000 gr/kWh	140,56 PLN
HOUSE ELCTR	[illegible]	1804,270 kWh	0,000 kWh	1680,385 kWh	1680,385 kWh	50,000 gr/kWh	[illegible]
ELECTRIC BOILER	0,000 kW	4648,968 kWh	2141,075 kWh	4646,098 kWh	2505,023 kWh	24,000 gr/kWh	601,20 PLN
FIREPLACE	0,000 kW	4868,002 kWh	2514,586 kWh	4868,002 kWh	2353,416 kWh	14,000 gr/kWh	329,47 PLN
COLLECTORS	0,000 kW	5808,760 kWh	1402,738 kWh	5778,202 kWh	4375,464 kWh	45,000 gr/kWh	1969,97 PLN
COLLECTORS POOL	2,662 kW	4666,346 kWh	910,311 kWh	4662,332 kWh	3752,021 kWh	45,000 gr/kWh	1688,40 PLN
GROUND FLOOR	0,000 kW	2931,964 kWh	1101,300 kWh	2931,064 kWh	1829,014 kWh	55,000 gr/kWh	1006,28 PLN
FLOOR	0,000 kW	4384,706 kWh	2022,025 kWh	4384,706 kWh	2362,681 kWh	45,000 gr/kWh	1063,20 PLN
HEAT PUMP HEAT	[illegible]	27,518 kWh	68,753 kWh	27,518 kWh	-41,235 kWh	14,000 gr/kWh	-5,77 PLN
DHW CIRCULATION	[illegible]	5260,936 kWh	5172,763 kWh	5260,881 kWh	88,118 kWh	10,000 gr/kWh	15,28 PLN
DOMESTIC HOT WATER	[illegible]	1640,262 kWh	848,748 kWh	1789,565 kWh	942,818 kWh	24,000 gr/kWh	228,27 PLN
	0,0 l/min	[illegible]	19,018 m³	40,192 m³	20,674 m³	7,50 PLN/m³	200,00 PLN

Figure 4 – Examples of energy and cost balances in the time range from 1 January 2011 to 31 December 2011

Energy and cost balances are also generated after a time range and price unit are entered. Another function allows the user to generate daily temperature diagrams for several metering points at the same point in time, which is necessary to analyse and optimize operating parameters of a controlled heating installation.

The system can also be used to track momentary power flow of specific heating circuits. One useful function allows the user to generate diagrams over a time range of one year.

It can be used to compare the courses of external temperature and the production and consumption of energy for individual circuits in different years, which are saved in the internal memory (Fig. 5).

CONCLUSIONS. Utilization of renewable energy sources in hybrid heating installations is becoming more and more widespread. It is therefore advisable, from the point of view of designing such installations, to obtain as many results as possible in wide time ranges and in various climatic conditions.

The online control, energy and cost balancing system DigiENERGY presented in this paper performs very well in a system producing thermal energy for practical purposes, and works excellently as a tool for collecting and archiving measurement data for further analysis when designing similar installations.

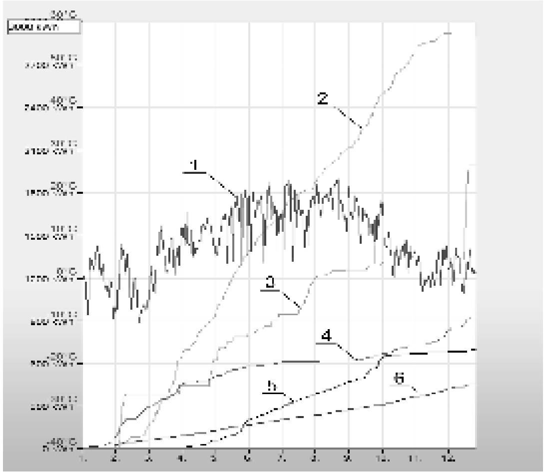

Figure 5 **–** Examples of annual diagrams from 2011; 1 – external temperature; *amounts of thermal energy*: 2 – collector circuit; 3 – fireplace; 4 – heating; *amounts of electric energy*: 5 – pool pump; 6 – control

The concept presented in this paper to use some hybrid installations with renewable energy sources also for research purposes in the form of the so called "distance laboratories" is new and original. It should be developed and refined in practice. The formation of a new research plane in that respect would allow for the integration of different teams involved in similar subjects related to the acquisition and utilization of energy from renewable sources. This applies in particular to international teams often located several hundreds kilometres apart.

Authors of this paper would be happy to cooperate with new teams interested in the problems presented here and willing to contribute new ideas and research programs.

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ЛАБОРАТОРИЯ ДИСТАНЦИОННОГО ОБУЧЕНИЯ С ИСПОЛЬЗОВАНИЕМ ГІБРИДНОЙ УСТАНОВКИ, ИСПОЛЬЗУЮЩЕЙ РАЗНЫЕ ВОЗОБНОВЛЯЕМЫЕ ИСТОЧНИКИ ЭНЕРГИИ

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Рассматриваются примеры реальных гибридных систем на базе возобновляемых источников энергии используемых в системах горячего водоснабжения и центрального отопления зданий. Эти установки оборудованы усовершенствованной системой управления, позволяющей потребителю контролировать потребляемую энергию и затраты. Такие установки предоставляют возможность дистанционного управления с четырьмя уровнями доступа, а также управления текущими параметрами в режиме реального времени через Интернет. Данные функции открывают путь к использованию подобных оборудованных установок в качестве лабораторий для дистанционного обучения. Они уже протестированы студентами сотрудничающих с нами университетов, занимающихся вопросами возобновляемой энергии.

Ключевые слова: солнечная тепловая энергия, система управления, возобновляемые источники энергии.

Стаття надійшла 12.11.2012.
Рекомендовано до друку
д.б.н., проф. Никифоровим В.В.