International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 5 (2017) pp. 578-581

Studying the Operation of Hot Water Supply System Based on Renewable Sources of Energy by the Results of Remote Monitoring

T.I. Koroleva
Candidate of Economic Sciences, Professor of the Department "Heat and Gas Supply and Ventilation", Penza State University of Architecture and Construction, 28, Germana Titova St., Penza, Russia.

A. A. Baklin
Candidate of Technical Sciences, Associate Professor of the Department "Technical Quality Management", Penza State Technological University, 1A/11, Baydukova Drive / Gagarina St., Penza, Russia.

V. R. Silakov
Junior Research Fellow, Penza State Technological University, 1A/11, Baydukova Drive / Gagarina St., Penza, Russia.
e-mail: svr007@bk.ru

Y. V. Rodionov
Doctor of Technical Sciences, Professor, Head of the Department "Road Transport Operation", Penza State University of Architecture and Construction, 28, Germana Titova St., Penza, Russia.

Abstract

Remote monitoring system allows to check and change the hot water operation settings of the student canteen on-line, as well as transmit the data stored for analysis to the local university network and the Internet. The data obtained in real time allowed to evaluate the production of thermal energy each heat generator in hot water system of the dining room and compare them with mathematical calculations.

Keywords: monitoring, hot water supply system, renewable sources of energy, solar collector, heat pump, controller.

INTRODUCTION

The trend of growing use of alternative sources of energy in the world remains unchanged, and the scope of their application is increasing due to their popularization in the information field and sophistication of technical solutions.

Nowadays hot water supply (HWS) systems based on the conversion of solar power are becoming increasingly popular in many countries around the world. The analysis of studies dedicated to the use of such systems has shown that the combined system based on flat solar collectors (SC) and air-source heat pumps (HP) is the most rational to be used as renewable sources of energy for HWS of a local object in Central Russia [1,2]. These devices are most effective for converting solar and latent air power into thermal one. A tubular electric heater (TEH) is normally used as a backup source.

MATERIALS AND METHODS

The structure of simulating a combined system by the example of a student canteen at the university can be represented in a simplified form as the calculation of the total calorific power of the solar heating system through the calorific power of the heat generation devices HP, SC and TEH.

Then the condition of the heating capacity balance of the system will be presented as follows [3]

$$q_{dhw}(t) = q_{wp}(t) + q_{eh}(t) + q_u(t), \qquad (1)$$

where $q_{dhw}(t)$ – total usage in the HWS system;

$q_{wp}(t)$; $q_{eh}(t)$; $q_u(t)$ – calorific power of HP, TEH and SC respectively.

Using the correlation between calorific power q_{wp} and power usage w_{wp} on the one hand and efficiency factor HPε on the other, as well as the linear relationship of thermal q_{eh} and electrical w_{eh} power of the TEH and the circulating pump in the system of active circulation of the SC w_{eh1}, the basic system of equations will be as follows:

$$\begin{cases} q_{dhw}(t) = q_{wp}(t) + q_{eh}(t) + Gc_p\left[\int_0^\tau t_d(\tau)dt - \int_0^\tau t_{main}(\tau)dt\right] \\ q_{wp}(t) = \varepsilon w_{wp}; \\ q_{eh}(t) = w_{eh}; \\ q_{eh1}(t) = w_{eh1}. \end{cases} \qquad (2)$$

To visualize the description of the processes and interrelationship in a simulated HWS system the latter can be represented as the structure given in Fig. 1.

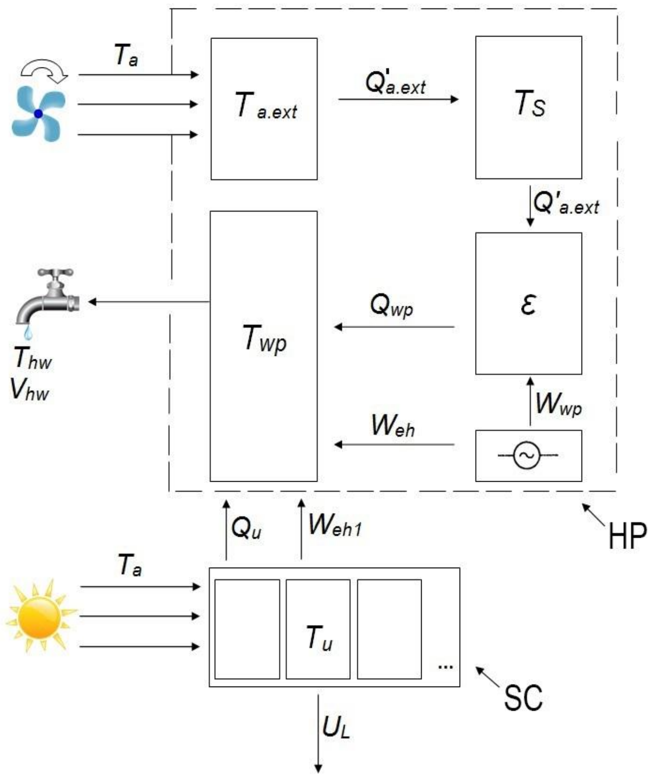

Figure 1. Block scheme of the model of a combined HWS system

The main generators of thermal power in the system are the HP "air-water" and the SC, the backup source being TEH. The outside air with the temperature $T_{a.ext}$ passes through the heat exchanger of the HP evaporator and gives heat $Q'_{a.ext}$ to the refrigerant. Consuming the electric power W_{wp}. the HP raises the refrigerant temperature at the expense of the HP efficiency factor and gives heat Q_{wp} to the heat medium circulating in the HP condenser. Thermal power is transferred to the first heat exchanger of the multifunctional HP tank at the temperature T_{wp}. Being small, heat loss in the HP-monoblock is not taken into account.

Another thermal power generator is the SC. Thermal power Q_u generated in the SC is transferred to the second heat exchanger of the multifunctional HP tank at the temperature T_u. There is also loss $U_{L.}$ in the SC system.

The TEH, built-in into the multifunctional tank for heating water in the HWS system, serves as a backup (spare) element in periods of hard frost or in emergency cases.

The electricity consumed by the HP is the sum of electric power amounts W_{wp} and W_{eh} generated by the energy compressor and the TEH respectively. In addition, a small amount of energy W_{eh1} is consumed by the circulating pump in the SC system.

RESULTS AND DISCUSSION

This approach makes it easy to calculate the proportion of thermal power generated by various heat generators for a certain period of time.

Fig. 2, for example, shows a diagram of the distribution of thermal power shares generated by heat generators in the canteen during the year.

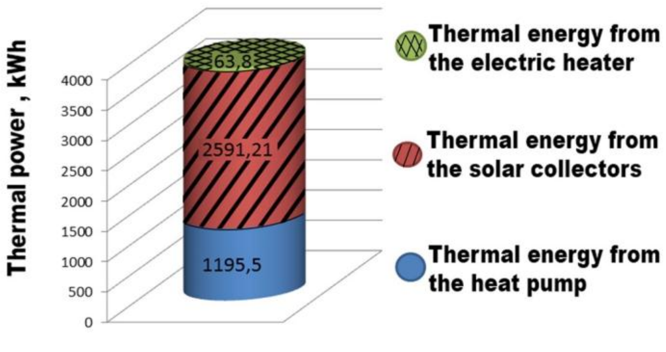

Fig. 2

Figure 2. Estimated distribution of thermal power shares generated by SC, HP and TEH

The data analysis showed that in the period from March to October the greatest part of the load in the preparation of hot water (from 60 to 85%) falls on the SCs. Through the HP heat exchanger tank the heat medium in them heats cold water, which is then sent to the HWS network. In the period from November to February the pattern changes, with 87% coming from the HP, 3% from the TEH and 10% from the SC [4].

This is due to the climatic features of Central Russia. Meanwhile, the backup TEH was activated only briefly during peak water consumption in January and February when the water temperature at the inlet was less than 7°C above zero and ambient temperature was 25-28°C below zero.

The scheme of the canteen HWS (Fig. 3) includes a system of electronic control and management of all processes on the basis of the trademark "SR1188" controller. The introduction of the advanced remote monitoring system has allowed of a new level of efficient processing of the data obtained from all the components of the HWS in the automatic mode.

The automation system, which controls all the devices, takes into consideration the features associated with the functioning of the equipment. The controlled information is saved to the controller memory card and then passed to the local university network and the Internet. This allows of effectively monitoring online the HWS work of the university canteen, analyzing the SC work in different periods of operation, the HP and TEH operating time, the consumption of electricity and hot water.

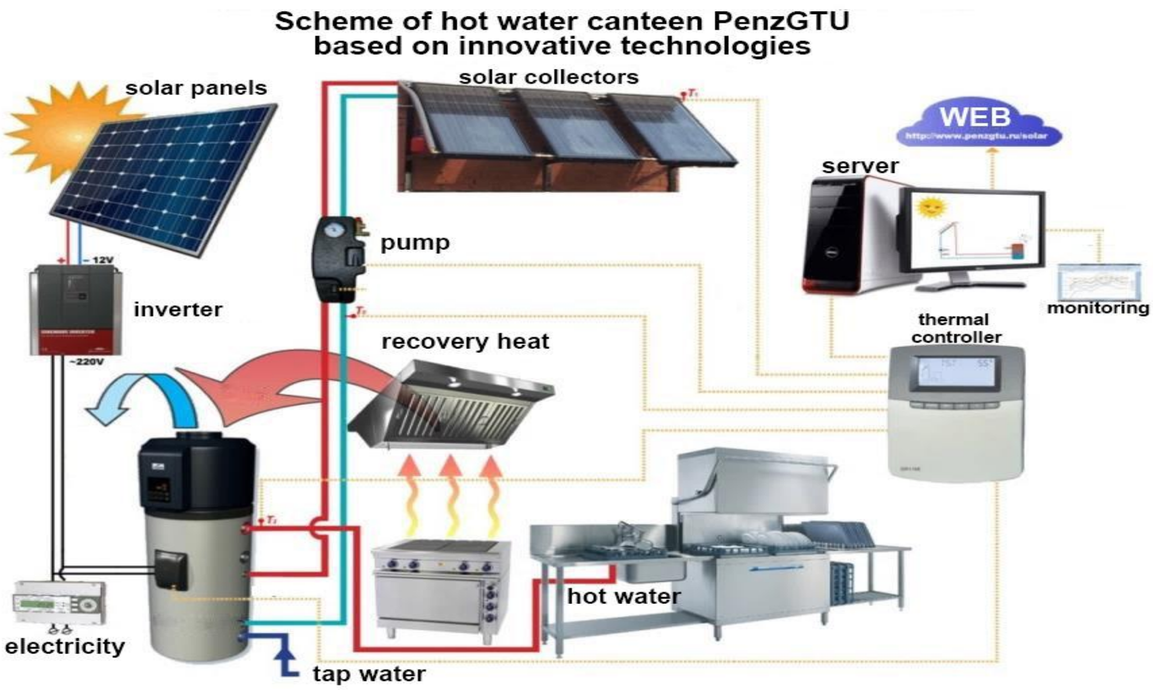

Figure 3. Scheme of the HWS of the student canteen in the university

To see the real HWS parameter values of the canteen (Fig. 4) online.

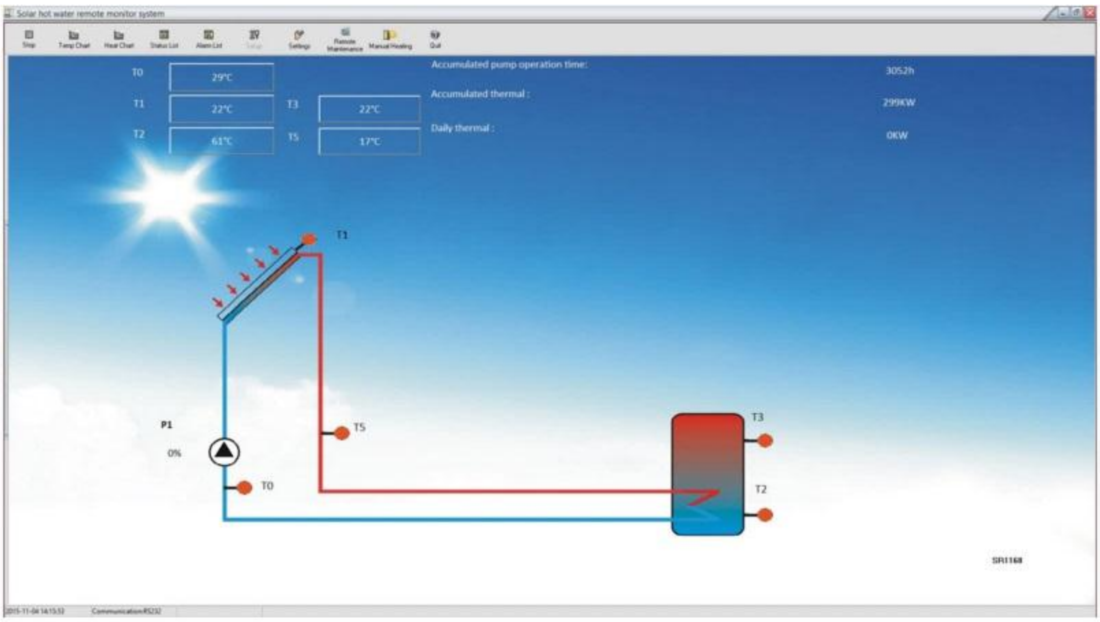

Figure 4. Typical HWS scheme at the university site

Processing the received data bank on heating temperature and HWS consumption parameters of the canteen allows of building approximating curves of temperature change T_o, T_1, T_2 and their regression models with coefficients of determination.

As an example, Fig. 5 presents diagrams for March 3, 2016. The analysed time interval is divided into two: “morning” – time from 5:00 to 10:59; “day” – time from 11:00 to 15:00, which corresponds to the canteen schedule. For each temperature change diagram T_o, T_1, T_2 approximating curves are built, each of latter is described by two mathematical models – for the “morning” time and “day” time respectively. The obtained coefficients of determination R^2 indicate strong dependence of the temperature (dependent variable y) on the time (the independent variable t) [4].

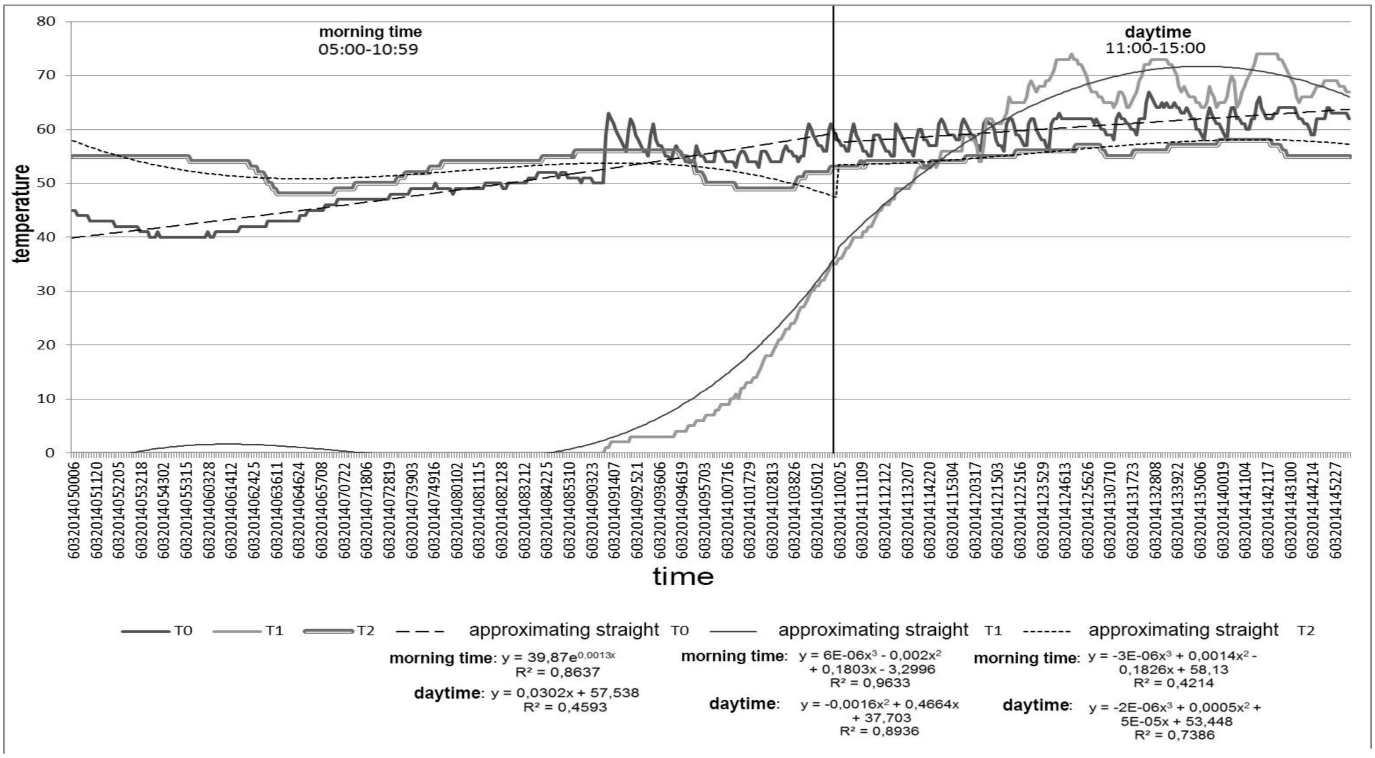

Figure 5. Diagrams of temperature changes T_0, T_1, T_2 depending on time

The automation system, which controls the equipment functioning, takes into consideration the features associated with the equipment involvement. In the two summer months, when the canteen is almost not working, the so-called "vacation mode" is on, when the heat medium circulation is intermittently switched on to exclude the heat medium stagnation in the SC, but in the reverse direction, to cool the absorbers.

The collected monthly and annual databases are actively used in the educational process of the university. On this basis several laboratory works have been devised. In addition, the actual data received have allowed of estimating the generation of thermal power by each heat generator in the HWS system of the canteen and compare them with the design values on a real-time basis (Fig. 7).

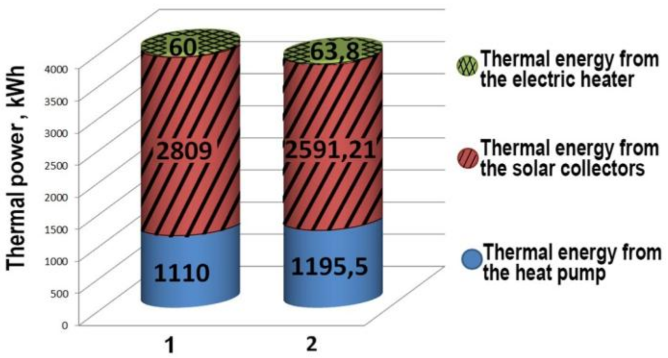

Figure 6. Distribution of the generated thermal power proportions in the combined HWS system in the canteen:

1 – theoretical data; 2 – monitoring data

CONCLUSION

1) One should note high conformity of theoretical data on annual average heat supply with empirical data, the margin of error for each type of power generation does not exceed 6-9%.

2) The use of remote monitoring system has allowed of accumulating and processing statistical data which formed the basis for the assessment of the work of the HWS system based on renewable energy sources.

3) This approach is realized in devising typical schemes of combined systems that use multiple sources of heat generation of both traditional and renewable energy.

REFERENCES

[1] Butuzov V.A., Bryantseva E.V., ButuzovV.V. Combined heat supply of premises based on the use of solar energy // Industrial energy. 2006. №12.: 39-41.

[2] Kharchenko N.V. Individual solar installations. M.: Energoatomisdat, 1991. 208 Pages.

[3] Deffi D.A., Beckman W.A. Thermal processes using solar energy. M.: Mir, 1977. 413 Pages.

[4] Silakov V.R. The results of comparative experimental studies of flat solar collectors with different absorbers as part of the solar water heating installation // XXI century: the results of the past and the problems of the present plus. 2015. №5 (27).: 82-88. (UDC 620.98 \662.99 \62-67)