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Study on Heat Pump Parameters Monitoring for Different Heat Exchanger Topologies

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Abstract

Achieving energy independence involves both knowledge and efficient use of classical energy resources, especially identifying new sources of clean renewable energy and increasing the efficiency of their use. This paper presents a study on parameters monitoring of a heat pump as a mechanical device used for heating or cooling by taking heat from the environment. Sources used are land and water, and heat exchanger is used in different constructive variants (mounted directly pipe, mounted spiral pipe, drilled shaft).

Key words: *renewable energy sources, data acquisition, monitoring, databases*

Introduction

One of the fundamental problems of the age we live in is supplying the necessary energy for human daily activities. Contemporary society has developed progressively and energy needs are satisfied in an overwhelming proportion using fossil fuels. Classical sources of energy based on oil, coal and natural gas have proven to be effective for developing technical and economic progress, while they have contributed and still contribute to the deterioration of the environment and human health [2]. On the other hand world's reserves of oil, coal and natural gas are in a continuous decrease while the costs for operating and identifying new deposits are in a continuous growth.

Current global concerns are directed to pollutant emissions reduction (Kyoto Protocol) and to supplying word energy needs. These led to the identification of new energy sources, renewable and clean, as well as to refine the methods and means of exploiting them.

Along with wind power and photovoltaic panels, heat pumps are part of the equipments used to operate renewable energy sources.

In recent years, the number of installations that use heat pumps has increased continuously, a recent estimation being between 10% and 30% annually [1]. The main factor for this increase is due to cooperation in the international field. Technological developments in heat pump equipment and the good results achieved using heat pumps, led to an increased number of people using this technology.

Current research focuses on the topology of the heat exchanger to reduce initial costs, but also to estimate and model the thermal response of soil [4]. The results underlie the development of hybrid systems and the design of new generations of heat pumps.

The authors present in this paper results obtained at different heat exchanger topologies. The heat exchanger is part of a pilot heat pump installation, located in the laboratory of Hydraulics, Thermotechnics and Reservoir Engineering Department.

Heat Pump Working Principle

Heat pumps are modern devices which transfer heat from one place to another. Operation of a heat pump is similar to a refrigerator (the same technology applied in a reverse way).

Heat pumps are based on two major principles:

- taking heat from outside air (operating as a home heating) or heat transfer to it (the operating system of a cooling housing);
- heat takeover or heat transfer is made from/to land or water.

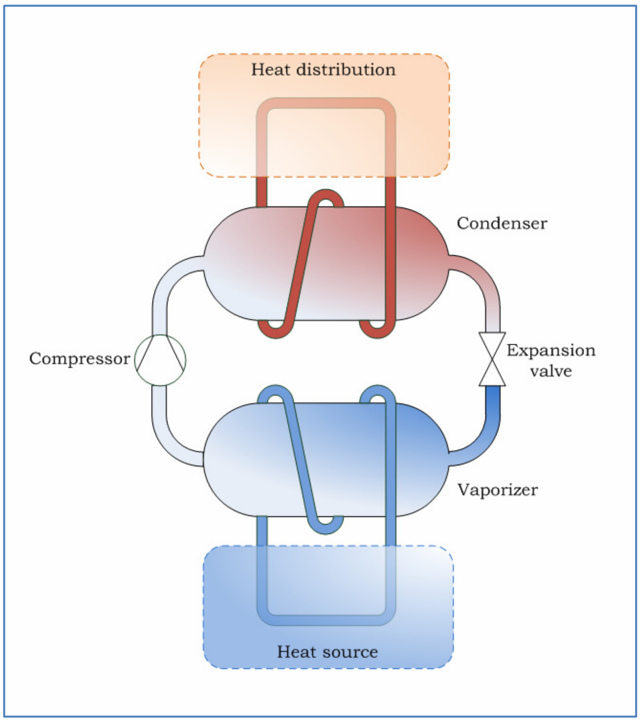

Fig. 1. Heat pump working principle

A heat pump is a system composed of: a source of heat, heat pump itself, the distribution and storage system of produced heat. In a closed circuit, inside the pump, a refrigerant liquid transport and transfer heat from the source to the distribution system. The heat from the environment reaches pump vaporizer. This is where the refrigerant liquid (which boils and evaporates at temperatures below 0^0 C) acquires and stores the energy extracted from the environment. Refrigerant volume now gaseous is reduced using a compressor. When refrigerant is compressed its temperature and pressure increase considerably. The compressed refrigerant having a high temperature reaches the condenser - a heat exchanger - where the heat is transferred to the heating system. The refrigerant is cooled during the heat transfer from condenser and from loosing pressure in the expansion valve, being ready for a new functioning cycle [3].

Pilot Research Installation

The research in renewable energy field cannot be made without a practical approach, so a laboratory for the study of renewable energy sources (wind power, solar energy and geothermal energy) is developed at the "Petroleum-Gas" University of Ploiesti (based on collaboration between Control Engineering and Computers Department and Hydraulics, Thermotechnics and Reservoir Engineering Department).

Geothermal energy is captured by means of heat pump which has as primary source the energy from soil and phreatic water.

Heat pump is a reversible pump with mechanical vapor compression, Hitachi SL-232 CV-C7LU rotary compressor and two heat exchangers Alfa Laval AC-30-EQ-40H, as vaporizer and condenser [6]. Heat pump laminar air valve is adjustable.

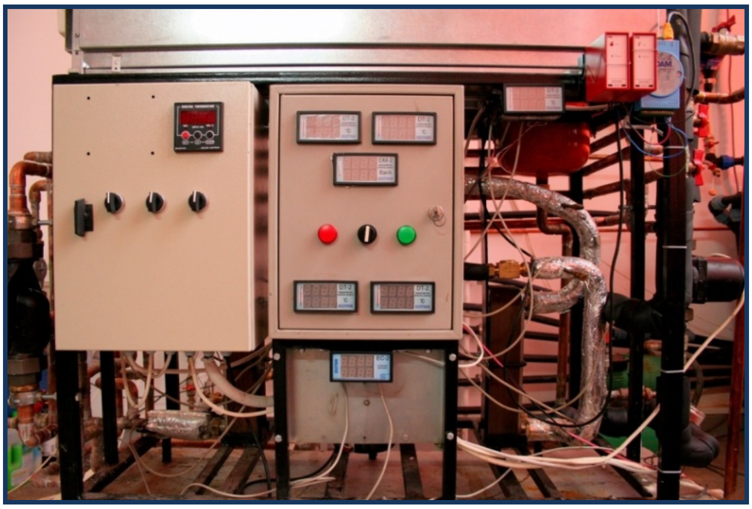

Fig. 2. Heat pumps control and monitor installation

Heat pump can produce heat using the following heat exchanger topologies:

- phreatic water shaft drilled at 15m with 4m hydrostatic level;
- simple polyethylene loop having total length of 60m, dug at 1m depth;
- spiral polyethylene loop having total length of 180m, dug at 2m depth;
- 40m vertical shaft with simple polyethylene loop.

In case of using phreatic water two shafts have been drilled, one being used for the extraction of water which will yield heat in the heat pump vaporizer, and the other being used for the reintroduction of water into the phreatic layer.

By using polyethylene pipes in the heat exchangers, heat carrier agent circulates through plastic pipes, without being in contact with the ground and without being consumed. This fact excludes the possibility of soil pollution. Because of polyethylene properties there are no pipes corrosion problems so the system has a long time of use (over 50 years). Movement of heat through the polyethylene pipes accomplishes heating exchange between them and the ground.

Software Monitoring Application for Heat Pump Parameters

In order to determine the evolution of heat pump parameters at modifying heat exchanger topology, an automated real time monitor system has been implemented.

The system developed to determine heat pump parameters consists of the following main sensors:

- temperature sensors for the entry / exit to / from the vaporizer;
- temperature sensors for the entry / exit to / from the condenser;
- sensors for temperature before and after valve rolling;
- sensors for temperature and pressure before and after the compressor;

- temperature sensors for the entry / exit to / from convector valve;
- sensor used for measuring heated air current speed through convector valve (this measurement is used to calculate the calorific power of the heat pump);
- 40 sensors to measure the temperature field of polyethylene pipes that comprise the body of heat exchangers.

The signals from sensors listed above are taken by 12 measuring and display devices which can be addressed into a RS485 local network. Those 12 measuring and displays devices are visible to Ethernet network through two converters RS485/Ethernet.

From software perspective, it was implemented a package of applications for automated monitoring of heat pump parameters, and further their on-demand visualization.

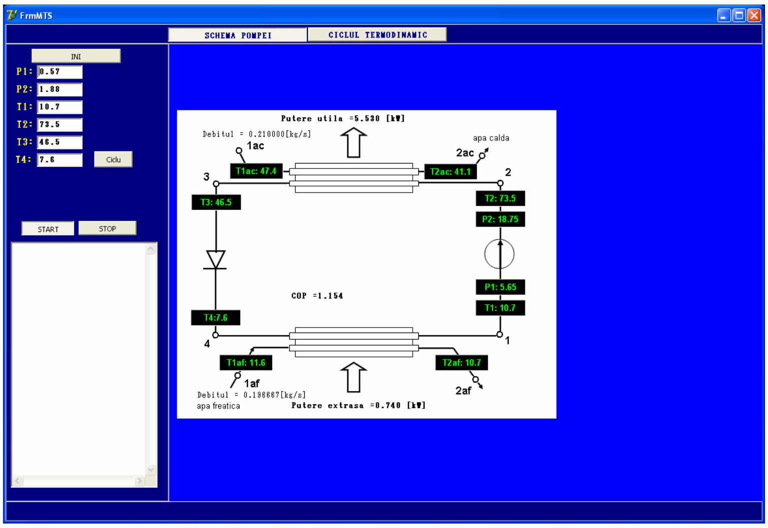

Fig. 3. Graphic user interface of heat pump parameters monitoring software application

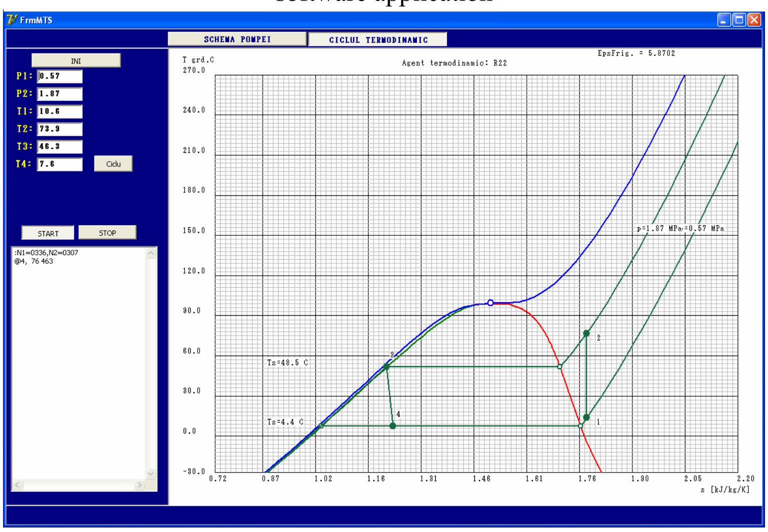

Fig. 4. Heat pump thermodynamic cycle

Development environment used to implement the software application was Borland Delphi and as database server MySQL was chosen.

The main screen of application GUI (Figure 3) shows graphically monitored parameters that characterize the heat pump working regime. When Ciclul termodinamic button it's pressed, the software application will generate automatically the current heat pump thermodynamic cycle, based on the values received from sensors acquired with a 20 seconds sampling rate. The time interval was chosen taking into account the inertia of the monitored system (over 20 parameters not evolving significantly).

Values from temperature sensors placed in the ground (in the area of heat exchange) are automatically acquired and stored in a database, where they can be viewed on request. Analyzing such data can provide important information on thermal response of the soil at different moments of time at different rates of movement of water through pipes and various topologies of heat exchangers.

Research Results

For each topologies of heat pump exchanger parameters were monitored, their graphically evolution in time being presented in figures 5, 6, 7 and 8.

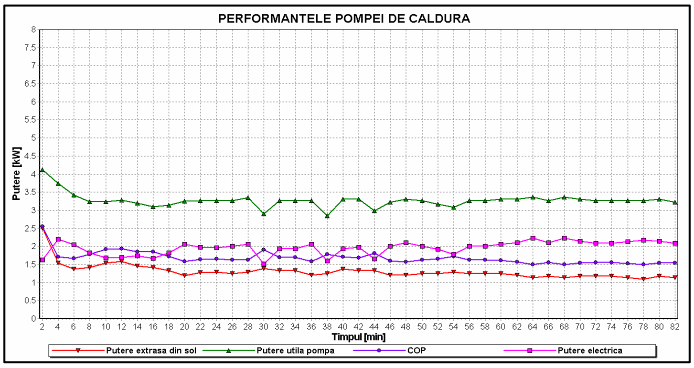

Fig. 5. Parameter's dynamic evolution – simple loop 60m

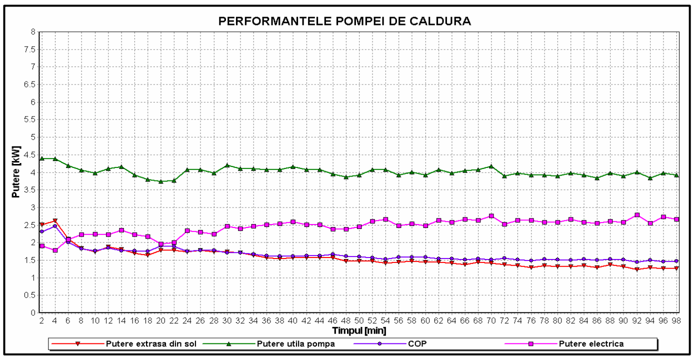

Fig. 6. Parameter's dynamic evolution– vertical shaft 40m

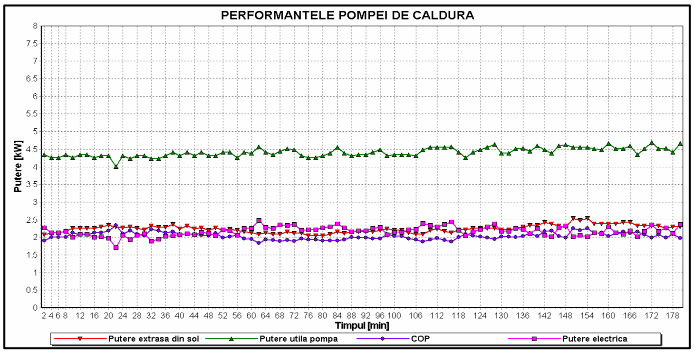

Fig. 7. Parameter's dynamic evolution– spiral loop 180m

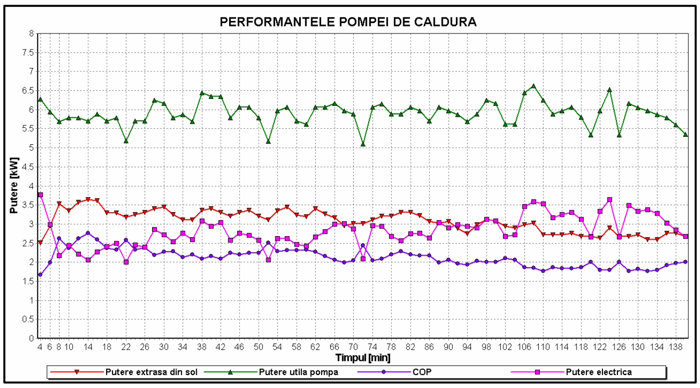

Fig. 8. Parameter's dynamic evolution – phreatic water

In the figures illustrated above, the behavior in time of thermal power extracted with the heat exchanger, as well as useful thermal power (hot water or warm air used for heating up), compressor's power consumption and performance heat pump coefficient (COP) are presented.

The most significant performances were obtained for heating exchanger – shaft with phreatic water, where heat extracted reaches maximum value (compared to the other heat exchangers) and is constant throughout the entire heat pump operating cycle. At the other systems, the heat extracted shows a decline in time, which affects the COP. The maximum values reached for COP were: 4.7 – shaft with phreatic water, 4.3 – spiral loop, 4.2 – 40m vertical shaft, 4.1 – 60m simple loop.

Conclusions

Due to collaboration between Control Engineering and Computers Department and Hydraulics, Thermotechnics and Reservoir Engineering Department, a research laboratory for renewable energy sources has been developed. This laboratory was the main research source for all results presented in this paper by the authors. Here it was developed a real time monitoring system for heat pump parameters, offering the possibility of on-demand data visualization.

The heat pump monitoring systems and thermal response of the ground has allowed for the first time to obtain complete data for a pipeline placed in the soil.

A numerical model for analyzing the interaction of thermal pipeline transport with the soil of geometry defined experimental system was developed in Borland Delphi.

Monitoring fluid transport process in the entire heat exchanger area was made.

Processing data obtained from monitoring system has allowed calculating the performance heating pump coefficient for each of the heat exchanger topologies. Taking into consideration all mentioned before, the authors recommend using shaft with phreatic water for achieving the best COP, compared to the results obtained with other heat exchangers.

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Studiu privind monitorizarea parametrilor unei pompe de căldură la modificarea topologiei schimbătorului de căldură

Rezumat

Realizarea independenţei energetice presupune deopotrivă cunoaşterea şi utilizarea eficientă a resurselor energetice clasice dar mai ales identificarea de surse energetice regenerabile nepoluante şi creşterea eficienţei utilizării lor. Lucrarea de faţă prezintă un studiu privind monitorizarea parametrilor unei pompe de căldură ca dispozitiv mecanic utilizat pentru a încălzi sau a răci prin preluarea căldurii din mediul înconjurător. Sursele utilizate sunt pământul şi apa, iar pentru schimbătorul de căldură se utilizează trei variante constructive (conductă montată direct, conductă montată în spirală, puţ forat).