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COMPUTER-AIDED DESIGN CONTROL SYSTEM OF THE HEAT PUMP

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Abstract. *The basic control problem. A review of CAD. Possible universal computer-aided design control system of heat pump.*

Keywords: control system; heat pump; computer-aided design.

Introduction

One of the most promising directions in the field of energy savings is the use of heat pump systems. The popularity of heat pumps has risen dramatically over recent years. This has not been purely for their high energy efficience ratings, but is also due to the numerous practical convenient, and environmentally friendly benefits that ownership and installation can bring. Heat pumps are often installed in homes to serve both heating and cooling need. The main advantage of the heat pumps system compared to other heating sources is the use of district heating in low-grade waste energy streams and natural warmth. Heat pump combines the functions of the boiler and air conditioning. Spending 1 kW of electricity to drive the pump, you can get 3.4 kW of heat energy.

Great promise is the use of heat pumps to heat water in buildings. The technology of heating and hot water supply of individual houses using heat pumps is very popular in developed foreign countries and now it's becoming popular in Ukraine. More than 30 years of successful operation of heat pumps abroad, including in countries where climatic conditions are similar to Ukrainian, confirmed the high reliability and effectiveness of the equipment. This, as well as increased energy rates suggest the prospects of its application in our country.

The heat pump is pumping low potential heat of the soil, water or air, even at a relatively high potential heat for heating the facility. Approximately 2/3 of the heating energy can be obtained free of charge from nature: soil, water, air, and only 1/3 of the energy you need to spend for the work of the heat pump. In other words, the owner of the heat pump saves 70 % of that at heating your home traditional way, he would regularly spent on diesel or electricity.

The main components of the inner loop heat pumps are (Fig. 1):

1. Condenser.
2. Capillary.
3. Evaporator.
4. Compressor that derives its power from the electrical grid.

In addition, the internal circuit is:

– thermostat that controls the heat pump;

– the coolant that circulate in the system (gas with certain physical characteristics).

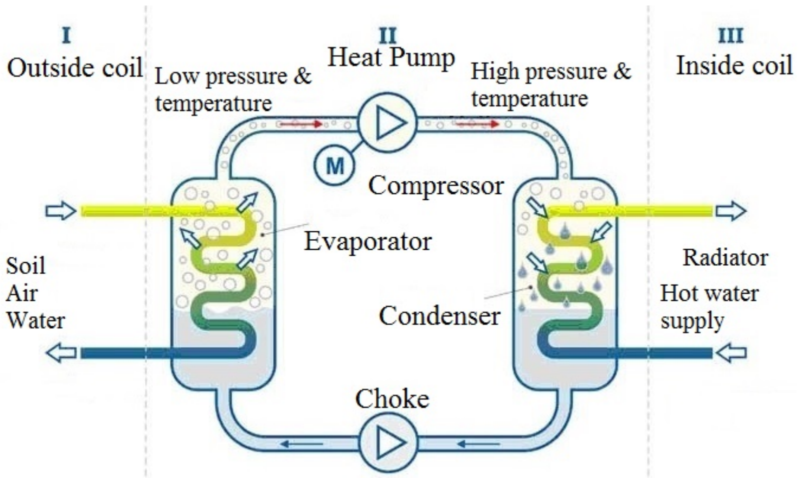

Fig. 1. Diagram of the heat pump

To heat the air inside the vehicle, heat is removed from the outside air or ambient temperature, and released to the inside air. When you heat a vehicle, the air conditioning process is reversed, with the compressor sending the high pressure vapor into the reversing valve which routes the vapor to the inside coil, which in the heating mode is the condenser coil. The high pressure vapor enters the inside coil (condenser) where it is cooled, and condensed into liquid by passing through the coil. The heat removed from the refrigerant is expelled to the inside air by the air movement system. The refrigerant leaves the inside coil as a high pressure liquid. As the high pressure liquid leaves the inside coil (condenser) it passes through the small capillary tube or tubes, which act as the metering or flow control device in the sealed system. The high pressure liquid refrigerant enters the outside coil (evaporator) in the controlled amount from the capillary tube. When the liquid enters the low pressure atmosphere of the outside coil (evaporator) it evaporates into vapor. When the evaporative process takes place, heat is removed from the air flowing through the outside coil (evaporator) and the air, which is now cool, is returned to the outside air (ambient) via the air movement system (blower assembly). From the outside coil (evaporator), the low pressure refrigerant vapor returns to the reversing valve. The reversing valve routes the low pressure vapor to the compressor through the suction line to start the heating process again.

The method of calculation of the heat pump control system

1. The losses of heat in the tank accounts for 63 W/h. Cold water temperature is 15 degrees, and the maximum water temperature, produced by the heat pump is 65 degrees.

2. The temperature of the mixed water is calculated by the formula

$$U = (t_1 - T) / (T - t_2);$$

$$T = (U\, t_1 + t_2) / (U - 1).$$

If $U = 1$, than $T = (t_1 + t_2) / 2$,
where t_1 is hot water; t_2 is cold water; U is mixing ratio; T is temperature wanted.

3. The time required to heat the water in the tank is determined as follows:

$$t = 0{,}00116\cdot(((V(t_2 - t_1)) / W),$$

where V is tank volume; t_2 is temperature of heated water; t_1 is temperature of cold water; W is electric power of heating element.

4. Temperature change in a second operation of the heater tank can be calculated using the formula

$$\Delta T = W/0{,}00116\cdot V\cdot 3600.$$

5. If the temperature in the tank is less than required, then turn on the heater by the heat pump and the tank. Since both devices work, the final temperature change is equal the sum. Similarly with the spent power.

The structure of the computer-aided design control system of the heat pump consists of three subsystems (Fig. 2).

Introduction of the necessary parameters: speed simulation, the required temperature in the boiler, the current temperature in the boiler, the boiler capacity in liters, current speed outpouring of hot by cold water, electricity used, time in seconds, tank heating power, heating power of the heat pump.

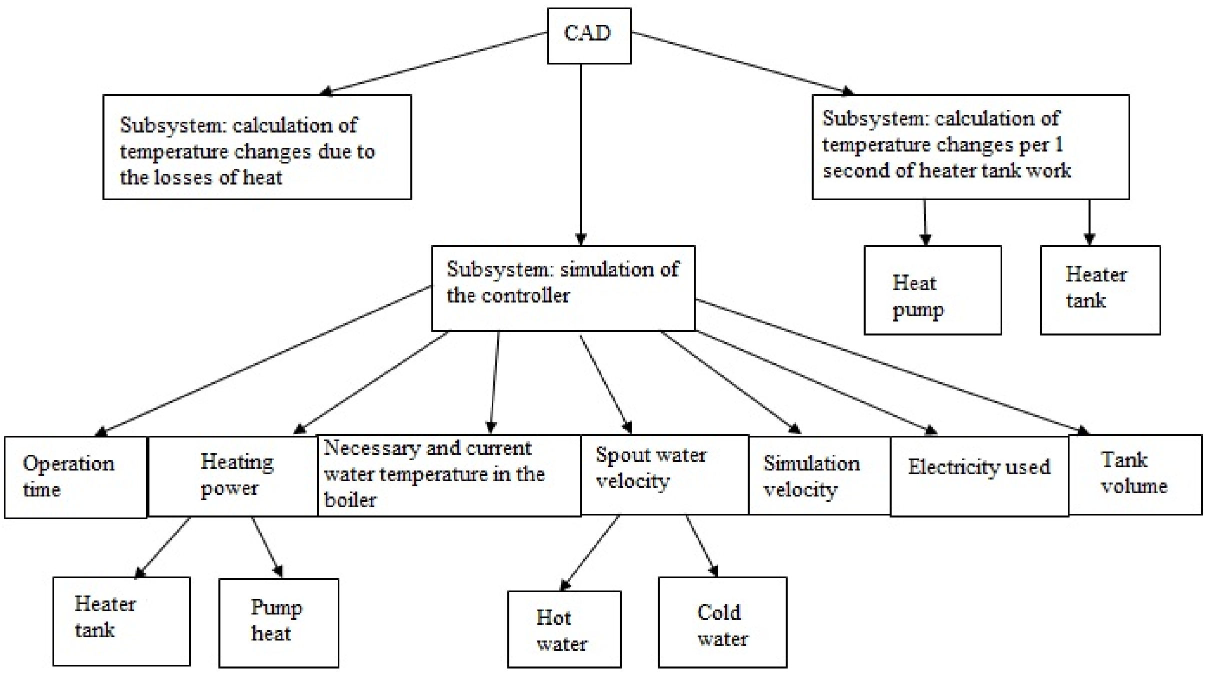

Fig. 2. Structure of the computer-aided design control system of the heat pump

Description of the controller simulation.

Zeroing of values calculated in the simulations.

Parameters assignment: losses of heat in the tank, the temperature of hot and cold water, mixing ratio.

The inclusion of process simulation by pressing the Start button, to activate the Pause lock button Start.

Calculation of the temperature change per second of work of the heater tank.

Calculation of temperature change per second of work of heater capacity (heat pump).

Calculation of the temperature change due to the losses of heat.

Description of changes in water temperature regulator in the tank.

Representation of the set temperature value on the screen.

Description of hot and cold water controllers changings.

Representation of the number of cold and hot water for a given number of seconds.

Representation of temperature increase per second of virtual time.

Representation of spent power per second of virtual time.

Representation of operating consumptions.

Calculation of the temperature changings in the tank after adding the cold water.

The inclusion of indicators of heat pump and tank.

Calculation of the time during which occurs heating to the desired temperature.

To get started with the program, the user must open a «pump» file on his computer. Then user will see interface of the program (Fig. 3).

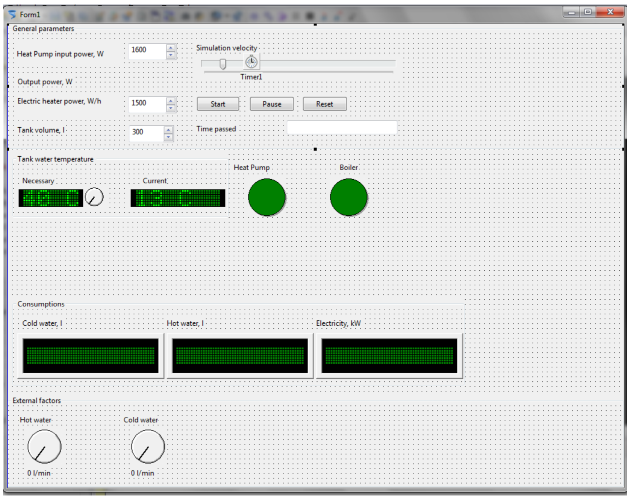

Fig. 3. User interface

The interface is divided into four parts: general parameters, the water temperature in the tank, consumptions and external factors.

1. General parameters.

The user can set the:

– power of his heat pump in W;

– power of electric heater in W/h;

– tank volume in liters;

– speed simulation (where 1 second of real time = 1 minute virtual).

Also, in this part of the interface are located the buttons “Start”, “Pause”, “Reset” and panel of elapsed time.

2. The water temperature in the tank.

The user can choose a necessary water temperature in the tank and next program will show the actual water temperature. Nearby are indicators of heat pump and hot water heater (when some of the devices is running – light is red, when the unit is turned off, then correspondingly the indicator is green).

3. Consumptions.

The panel shows consumption of hot, cold water in liters and power consumption in watts.

4. External factors.

The user is able to switch on the hot or cold water with different capacity.

Control example

This program simulator to control the heat pump allows the user to select the appropriate information for him, namely its heat pump capacity, electric heater capacity, tank volume, speed of simulation (Fig. 4).

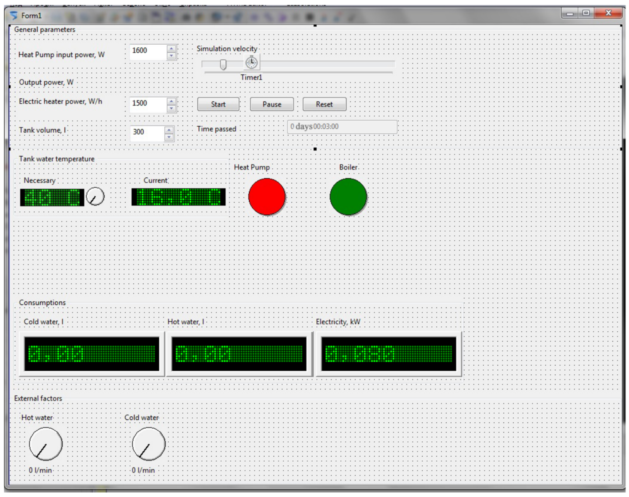

Fig. 4. The simulator program with heat pump on

Selected such information:

– heat pump power: 1600 W;

– electric heat power: 1500 W;

– tank volume: 300 l;

– tank temperature wanted: 40 degrees.

External factors:

– hot water: off;

– cold water: off.

For example, turn on the hot water too with capacity 1.55 l/min.

The program has calculated consumption and time (Fig. 5).

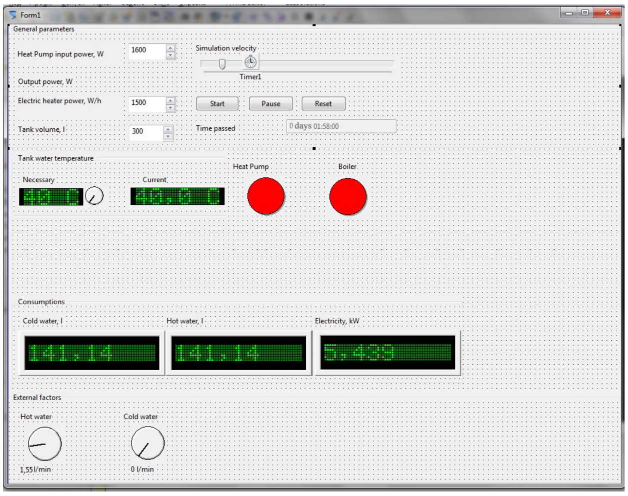

Fig. 5. Program process with heat pump and boiler on

At the beginning of the experiment worked only the heat pump (red indicator) with power 1600 W. Then turned on the tank with power 1500 W/h. Water temperature heated with heat pump and tank to desired 40 degrees for 1 hour 58 minutes. Electricity consumption is 5.439 kW. Cold and hot water consumptions are 141.14 liters.

Conclusions

The heat pump uses the heat dissipated in the environment of land, water, air. Spending 1 kW of electricity to drive the pump, you can get 3.4 kW of heat energy. The most important feature of heat pump systems is flexibility regarding the type of energy used (electrical, thermal). The heat pump will not only save money but also saves health tenants and their heirs. The unit does not burn fuel, and therefore not harmful formed oxides such as CO, CO_2, SO_2, Pb_2, therefore, using heat pumps is good for our planet.

The practical part of this work includes software of computer aided design control system of the heat pump, which allows to increase the performance of these devices, to reduce the cost of hot water, to reduce the time for investigation of the heat pump. To write this program there were analyzed methods of calculating the heat pump control system installation, designed the structure of computer-aided design to control heat pumps. This program allows the user to select the appropriate data for its building, namely its heat pump capacity, electric heater capacity, tank volume, simulation speed, provides an accurate calculation of the cost of electricity, cost of cold and hot water, showing the time over which these costs occured and etc. Thus, this program allows the user to explore the exact process of heat pump and monitor all the consumptions. The results of this study can be used by enterprises in the implementation of projects using heat pumps.

References

[1] Yantovsky, E. Y.; Levin, L. A. “Industrial Heat Pumps.” *Energoatomizdat*. 1989. (in Russian).

[2] Volov, G. Y. “Heating system and ventilation modeling.” *Energovent*. 2007. (in Russian).

[3] Arsenyev, V. M. “Energy-saving heat pump technology.” *SumDu*, 2009. (in Ukrainian).

[4] Heinrich, G.; Nastler, V.; Nayork, H. “Heat pumps for heating and hot water.”, *Stroyizdat*, 1985. (in Russian).

[5] Ray, D.; Macmile, D. “Heat pumps”, *Energoizdat*, 1982. (in Russian).

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В. М. Синєглазов, М. О. Гелеверя. Система автоматизованого проектування системи контролю теплового насоса

Розглянуто системи автоматизованого проектування системи контролю теплового насоса.

Ключові слова: система контролю; тепловий насос; автоматизоване проектування.

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В. М. Синеглазов, М. А. Гелеверя. Система автоматизированного проектирования системы контроля теплового насоса

Рассмотрены системы автоматизированного проектирования системы контроля теплового насоса.

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