

Energy Optimization of an Installation of Reversible Geothermal Heat Pump

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The present agents of society are demanding more rational harnessing of energy and its more efficiency approaching. Geothermal energy is a renewable energy which uses the heat of the ground and besides, it can be used by everybody in all the world. About 10 meters below the Earth's crust, the Earth stays nearly a constant temperature between 283 and 288 K in nearly all locations. So geothermal drilling is a process whereby heat is taken from the Earth and used in a productive way for energy needs. The low enthalpy geothermal energy is more and more approached through the heat pump. So it is necessary to establish criteria to improve the efficiency of these devices as a way in both heating or cooling.

The scope of this project is to study and to improve the ideal dimensions of the heat exchangers of the condenser, the evaporator and the desuperheater over a commercial prototype of a heat pump. For that, we have been monitoring the complete installation to study the pressures, the temperatures and the flow meters of the whole circuits. The purpose is to realize the simulation, the design, the installation and the monitoring of the new components to allow an experimental energy optimization.

1. Introduction

Heat pump is a device which can use the heat of air, water or ground as a heat source. These devices operate on an electrically driven vapor-compression cycle. Geothermal heat pumps can produce heating or cooling using the heat of the ground that kept a constant temperature from a certain depth. In these cases, heat pumps normally have to stop operating when those want to reverse the cycle to produce heating or cooling. Besides, some heat pumps produce domestic hot water (DHW) in the desuperheater where they take advantage of the sensible heat of the exhausted gas from the compressor.

The majority of geothermal heat pumps are manufactured in the north of Europe; nevertheless the environmental conditions in the south of Europe are milder than in the north of Europe. When these devices have to reverse the cycle of production some time is needed to change the circuits and controls to produce heating or cooling depending on the thermal demand according to environmental conditions.

In this way, several works analyze the production of heating/cooling and the DHW by different ways (Hepbsali and Kalinci, 2009; Cui et al., 2008). The production of DHW

has also been analyzed through the use of the sensitive heat of coolant condensation as overheated gas after the compressor and as of the subcooled liquid after the condenser (Shao et al., 2004; Palm, 2008). It is also possible to study the improvement of the heating capacity of an electric heat pump, using other sources of heat as the recovered heat and the cooling of engine block as exhaust gases (Kim et al., 2009).

1.1 Coolants

On the other hand, the properties of the working fluids must be considered when selecting a type of device. Among the used working fluids in heat pumps, the R22 has been substituted for pure fluids as the R134a, used for low pressures, or by zeotropic mixtures, like the R407C, or almost-azeotropic, as the R410A, used for greater pressures. Each one of these coolants has its own specific characteristics. Besides, other experiences determine the optimum work conditions of coolant mixtures in heat pumps (Comakli, 2009; Papadopoulos et al., 2010).

Between the characteristics more important it must be cited that:

- the evaporating pressure must be enough high to the desire evaporation temperature, and this pressure must be higher to the atmospheric pressure.
- the vaporization heat must be the highest possible, so the heat transfer is carried out with the less quantity of coolant, and the specific volume to the evaporation temperature must be the lowest possible, and thereby the size of compressor will be more little.
- the condensing pressure to the room temperature must be lower and the discharge temperature must be the lowest possible.

In the experiments which are carried out, it was used the R407C in the geothermal heat pump with a critical temperature of 359.2 K (Navarro et al., 2003) and the R410A in the air-water heat pump, but not ruling out the possibility of testing other available commercial coolants.

2. Experimental section

The installation is composed of a reversible geothermal heat pump, a tank of 732 L, a tank of 283 L and a tank of 250 L (Figure 1 and 2). Geothermal heat pump has a heating power of 7.5 kW and a cooling power of 7.3 kW. This could be the energetic demand of a domestic house. All of the installation was built with a pipe of 25 mm in copper with the main elements of safety as check valves, auto air vents or filters.

This research is exclusively centred in the study of the function of all of the elements of the geothermal heat pump. So no drilling has been made in the earth to use it as a heat of source. That is, the design of the installation was made without the approaching of the heat of the earth.

That is why, the design of the installation was made using a tank of higher size as a heat source, as if it were the Earth. Thus it was necessary to acquire an air-water heat pump to obtain the ideal conditions in the biggest tank. This was made due to the experience with another geothermal built installation, in which two drillings of 80 m and 100 m were made.

Besides the own dissipate heat was approached through a heat exchanger with the biggest tank. So the tank of 283 L (heat or cold) dissipates energy against the tank of greater size through a heat exchanger depending on the time of the year.

With aid of a selector of four valves (Figure 1, 4v), each tank can make the water circulate either from the upper part or from the lower part, depending on the operation conditions of the heat pump. The tank which simulates the wells maintains the conditions desired with the aid of the air-water heat pump (Figure 1, awHP) situated outside.

2.1 Data acquisition

The installation is integrated by 6 circuits. For that, it is necessary to control a great quantity of items to study the energy and mass balances. So, the data acquisition is compounded by the following items:

- 28 temperature sensors. Two of them are Pt-100, used for measuring the room temperature. The rest are Type T thermocouples, which have been selected for their little response time ($t_{99} = 2$ s).
- 5 pressure transmitters. These sensors are installed in the R407C internal circuit of the geothermal heat pump.
- 6 flow meters to measure the flow of water through the 6 circuits. All of them are DN25, except from the circuit of GHP-Tank DHW. In this case, it is DN06 due to the flow in this part so inferior to the rest.
- One electricity meter. This is necessary for counting the consumption of the compressor. With this parameter, it is possible to define the coefficient of performance completely.
- All this equipment is controlled by one Omron PLC (CJ1M).

The entire sensors (except temperature) give the information by 4-20 mA protocol. Their places allow to know all the heat exchanges between the heat pumps and the tanks, as well as the thermal stratification of the tanks.

The Omron PLC can accept both 4-20 mA protocol and the direct connection of a thermocouple, as well as to act on a relay.

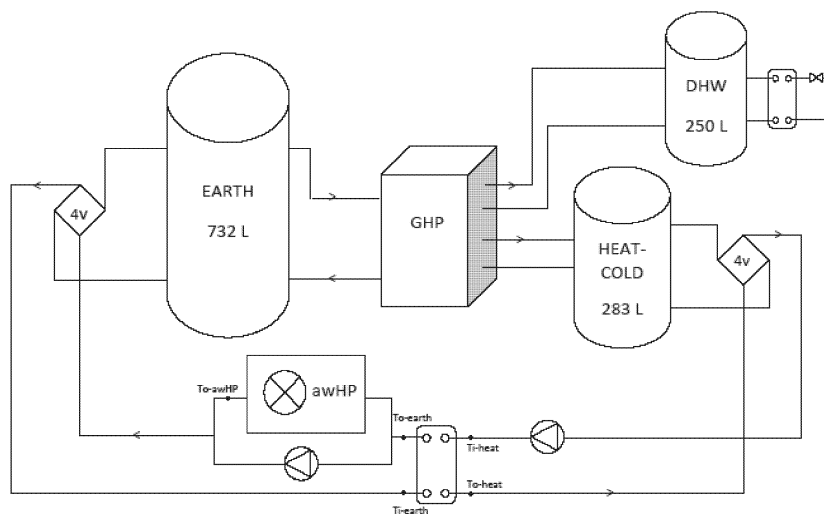


Figure 1: Scheme of the complete installation of heat pump.



Figure 2: Photograph of the complete installation of heat pump.

3. Results and discussion

Actually the first tests have been done with the whole installation. In Figure 3 it is shown the variation of temperatures through the heat exchanger. The symbols of T_i and T_o represent the temperatures of in and out respectively. The energy of the heat/cold tank is transferred to the Earth tank in the heating circuit.

During the first 15 minutes, the geothermal heat pump is turned on and the air-water heat pump is in cooling way. At 13:00 o'clock the GHP is turned off, which produced the heating temperature remained stable without interferences. At 13:06 the awHP is turned off, which produced the temperatures of the awHP are equal. At 13:12 the temperature of the heating tank decreases suddenly.

It is localized several susceptible points to improve that it has already been arranged. One of these points was that the air-water heat pump was connected in serial to the biggest tank. So when it was necessary to dissipate heat through the heat exchanger, there was a problem if the air-water heat pump had to heating the biggest tank, because in this case the heat pump produce an heat contribution higher that the geothermal heat pump could produce. This is resolved with the introduction of the circulating pump in parallel with the air-water heat pump (see Figure 1).

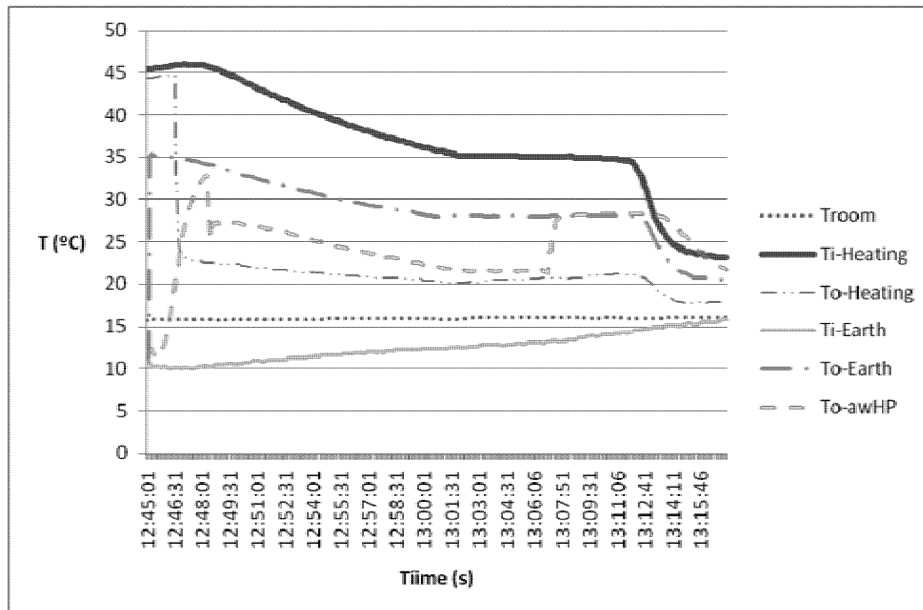


Figure 3: Variation of temperatures through the heat exchanger.

On the other hand, although each circuit had his expansion tank through the owner of the geothermal heat pump, it was necessary to introduce an own expansion tank to protect the storage water tanks and the other parts of the installation. Besides it was putting pressure relief valves in the tanks.

Too the biggest tank has a barrier to produce stratification. For that, it has been introduced a little circulating pump between the superior and inferior parts. It tries to break the stratification in the biggest tank, because this tank represents the conditions of the Earth.

Between the possible improvements it has been thinking to change the circulating pump of the geothermal heat pump which produces the domestic hot water. This change would be to substitute this circulating pump by other that it has a variable speed control. Moreover it has been thinking to introduce a three-way control valve to the exit of the compressor. It would share out the flow of exhaust gas between the production of domestic hot water in the desuperheater and the production of heating/cooling water in the condenser.

4. Conclusions

A geothermal installation of heat pump has been designed and totally monitored with temperature and pressure sensors, flow meters and electric energy counters, so it is possible to know the transfer energy in each instant and in each zone.

In this installation, it has been analyzed the heating/cooling of a heat pump and the domestic hot water production by means of the sensible heat recuperation of the desuperheater gas exhausted from the compressor.

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