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Technological solutions to increase the thermal capacity of soil and the efficiency of heat pump soil- water

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Abstract: **When we design a heating system for buildings using a heat pump soil- water is necessary to design solutions to maintain the heat capacity of soil at high level. If we don't take in consideration to maintain the heat capacity, in winter during the exploitation of heat pump the risk is to dry the soil and as a consequence the efficiency of the system decrease. In this paper we present three variants to keep the soil capacity up for a good exploitation of the heat pump. The variants are describe in a projects develop at Transilvania University.**

Keywords: dry, heat capacity, heat pump, thermal collector.

1. INTRODUCTION

The revision of the Energy performance of Buildings Directive (EPBD) introduced, in Article 9, Nearly zero energy Buildings (nZEB) as a future requirement to be implemented from 2019 for public buildings and from 2012 for all newly constructed buildings. The directive defines nearly zero energy buildings as follows: ”A nearly zero energy building is a building with a high energy performance and this low or nearly zero energy requirement should be covered to a large extended from renewable sources, including energy produced on site or nearby”[1]. According with Energy performance of Buildings Directive it is necessary to establish the building's energy balance within which the contribution of energy from renewable sources to the building's energy consumption can be measured or calculated. Today, the use of fossil fuel energy resources has degrading effect on earth's atmosphere. In this situation it is imperative to invent alternative technologies which can generate energy in more efficient way. Most part of energy is consumed for heating and cooling in buildings. Until this time a lot of study was performed to identify the important factors affecting the thermal performance of the ground heat exchanger [2]. The studies concluded: thermal conductivity of soil plays a vital role in the heat transfer process. The heat transfer fluid velocity, there by mass flow rate was an important parameter affecting the amount of heat exchanged with soil [2], [3], [4], [5]. In the area of heating of buildings, the alternate way to reduction the greenhouse gases is by utilizing the heat storing capability of the ground. Ground source heat pump systems use new technologies that uses less variable soil temperature to provide comfort in living spaces [5].The different types of Ground Source Heat Pump systems are open loop and closed loop heat exchanger, ground coupled or direct expansion loop configurations. The heat exchanger could be vertical or horizontal, however the most widely used are closed loop, ground coupled with vertical heat exchangers. The vertical heat exchangers are expensive and drilling costs vary depending on the soil composition. Several researchers have reported the results of their Ground Source Heat Pump studies, which have contributed to remarkable progress to the field. The researchers providing fundamental theories and references for design and operation for a Ground Source Heat Pump [6]. Esen et al. [7] carried out an experimental test at a room located at the University of Firat, Elazig, Turkey. The test results were obtained and compared to the numerical simulation. Esen et al. [8] further explored the energy and exergy efficiencies of the GSHP system with two horizontal ground heat exchangers. Wu et al. [9] studied thermal performance of slinky ground heat exchangers by both numerical modeling and experimental verification. Nam and Chae [10] created a tool for optimum design of energy-foundation systems integrated with horizontal GHEs. Selamat et al. [11] examined optimization methodologies of horizontal GHEs by employing different structures and piping materials. The first law and second law of thermodynamics play an important role in analyzing system performance. The first law deals with the energy balance of the system whereas the second law focuses on entropy generation and exergy effect. For geothermal heat exchangers, which use the ground as a renewable energy, thermodynamic irreversible is a criterion in their operation. The calculation of entropy as a function of the average temperature of the fluid inside it and the operating cost offers a a perspective on optimizations [12]. The calculation of the entropy according to the average temperature of the fluid inside is:

$$N_s = \frac{S_{gen} x T_{f,a}}{Q} \qquad (1)$$

Sgen - represents the generated entropy,
Tf,a - represents the average fluid temperature and
Q - represents the energy provided by soil.

The average temperature of the thermal fluid is directly influenced by the soil temperature, which is approximately equal to the outlet temperature. To increase this temperature external energy must be used. Next, we propose to present three solutions for increasing the average temperature of the fluid so as to practically maintain the value of the coefficient of performance of the ground coupled heat pump at high value and avoid soil drying. Almost all technical projects that propose solutions for the production of thermal energy using ground coupled heat pumps do not also propose solutions for soil maintenance to avoid the soil drying.

2. EXPERIMENT DESCRIPTION

2.1. Humidification continue of soil with an horizontal collector coupled with heat pump

At Transilvania University of Brasov few years ago we design a heating system with a heat pump coupled to a horizontal thermal collector. In fig1 we present the position of thermal collector and what we propose as a solution to increase the thermal capacity of soil. Thermal collector is connected with a heat pump soil –water in building L12.We design a system of pipes who discharge the waste water on thermal collectors from the station of treatment.The color of this pipe is brown in fig1.

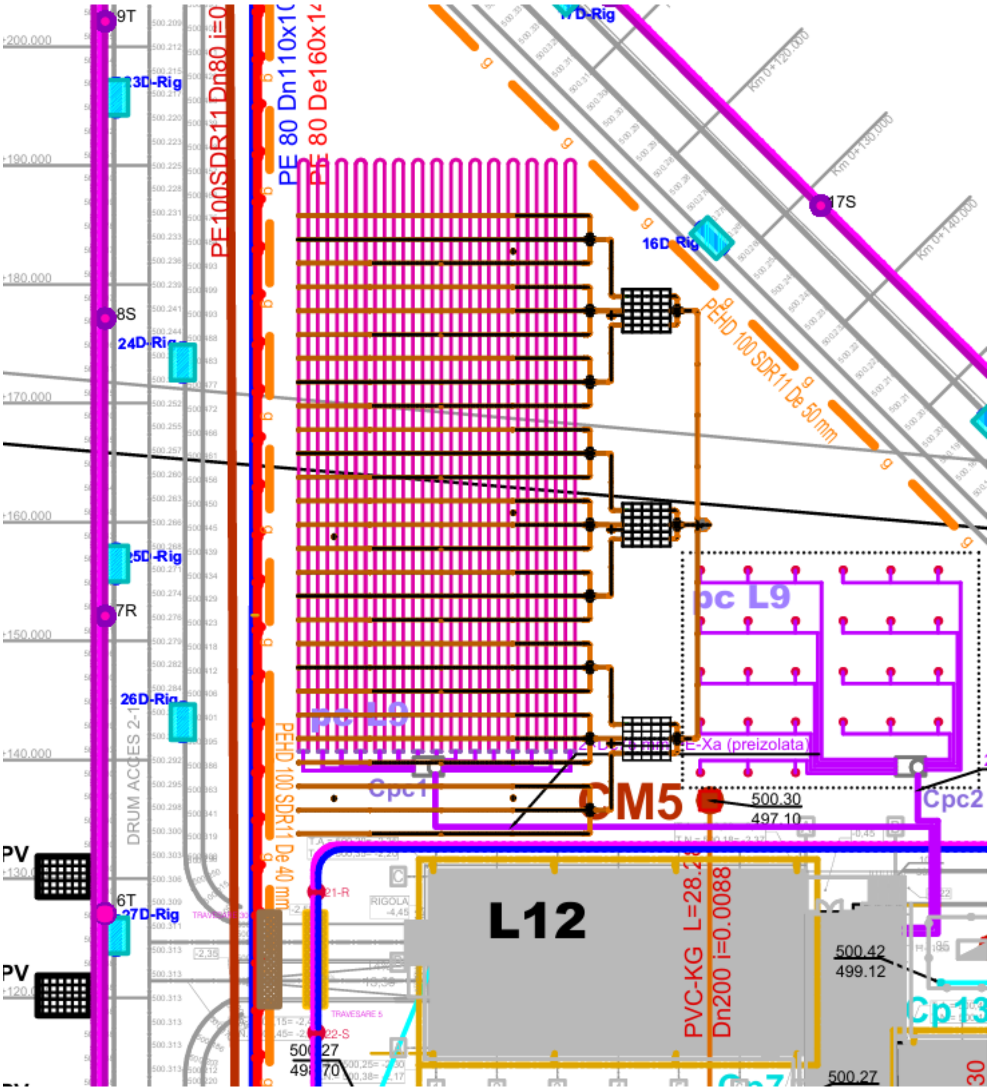

Fig. 1 Position of horizontal thermal collector coupled with L12

In figure 2 we detailles the position of humidification tubes above to horizontal collector. The question is what we get with this solution?. According with this solution the thermal collectors are permanent humidificate. The soil is not in danger to dry.

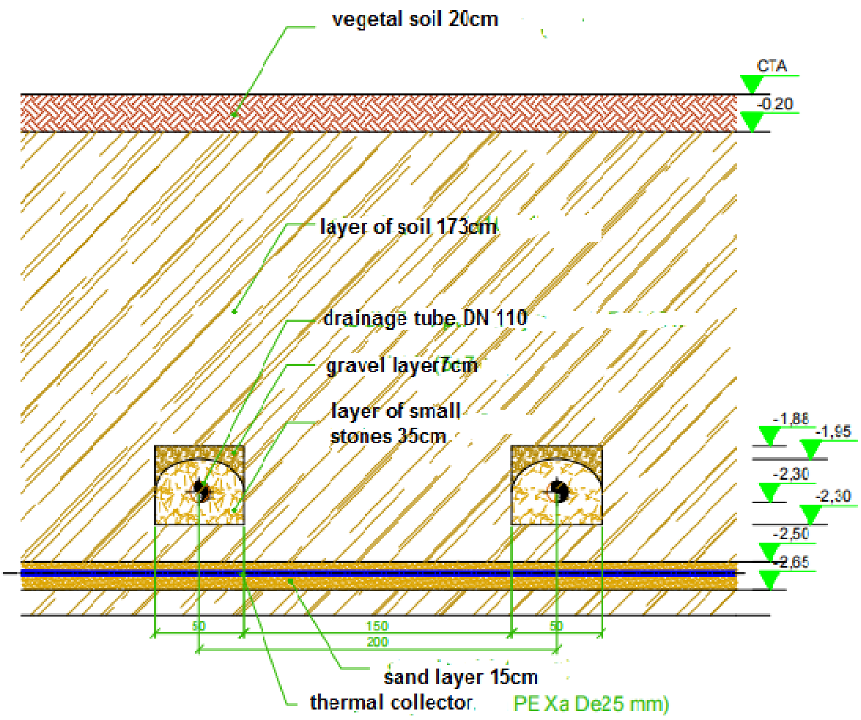

Fig. 2 Assembly details of humidification tubes on thermal collector

2.2. Passive cooling solution in building with a heat pump soil –water

Passive cooling is the least expensive means of cooling a building, especially in environmental terms. There are many ways you can design or modify your home to achieve comfort through passive cooling. Passive cooling is becoming more important as our climate changes. Climate change will see our average temperatures increase, and extreme events such as heatwaves occur more often. With careful design for passive cooling, we can keep our homes comfortable and reduce energy costs.In building L12 (Fig.1.) we designed the thermal plant - Heat pump soil-water coupled with a gas boiler.In this schema we designed a passive cooling system. In building L12 the heating system is assure by radiation, assembly in ceilings. The schema of heating plant is presented in Fig. 3. This system take the heat from inside the building and send her in the ground in summer time This system should be realized where a heat pump soil -water is design. In this way the soil is regenerate continue.

2.3 Solar system connected with primary circuit to heat pump soil –water

This technical solution is use to rise the heat capacity of soil, in our case a horizontal thermal collector connected with a heat pump, is presented in fig.4. Solar system is connected to a classic system of heat pump. The thermal agent from primary circuit of Heat Pump is preheating when the heat pump work. When the pump doesn't work and the agent from boiler of solar system has temperature, this energy is send to the soil. The soil is regenerate, in summer in special.

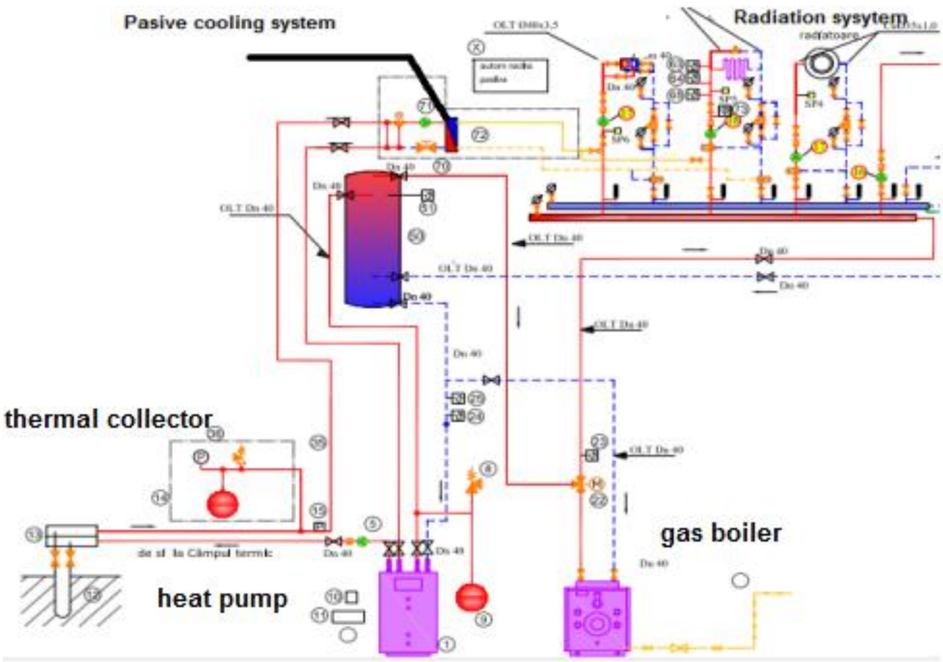

Fig. 3 Heating system plant with passive cooling

The question is what happen with the system after 1-2-3 years in exploitation. The designers should thing how to regenerate the soil. The solutions must be describe in technical project from de beginning.

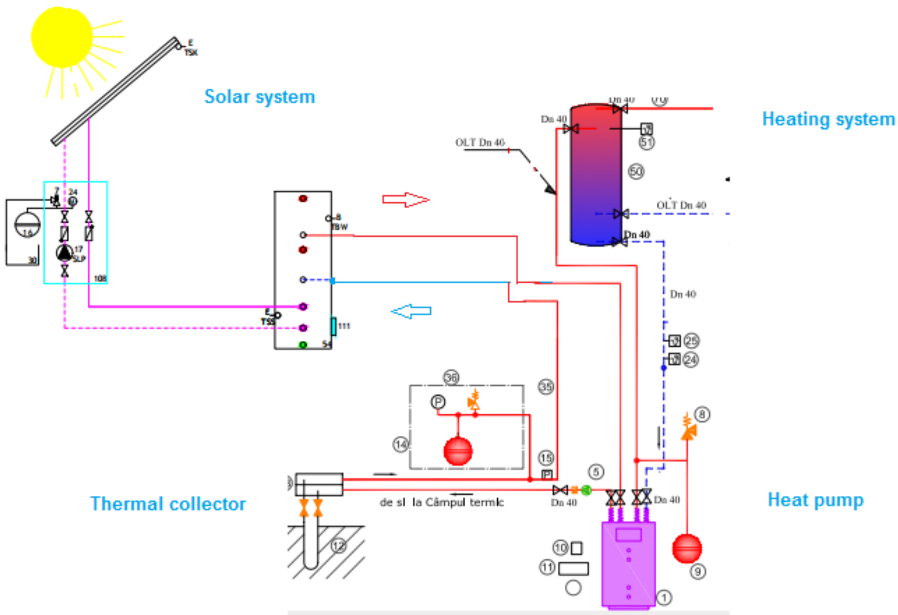

Fig. 4 Solar system connected to a heat pump soil – water

The solutions presented in Fig 4 will assure the energy in soil almost 100% when the pump don't work and aproximative 20 % from energy deliver to the buildings when the pump work. Because is a European Directive about how we use the renewable energy is important to find solutions for maintenance the all system.

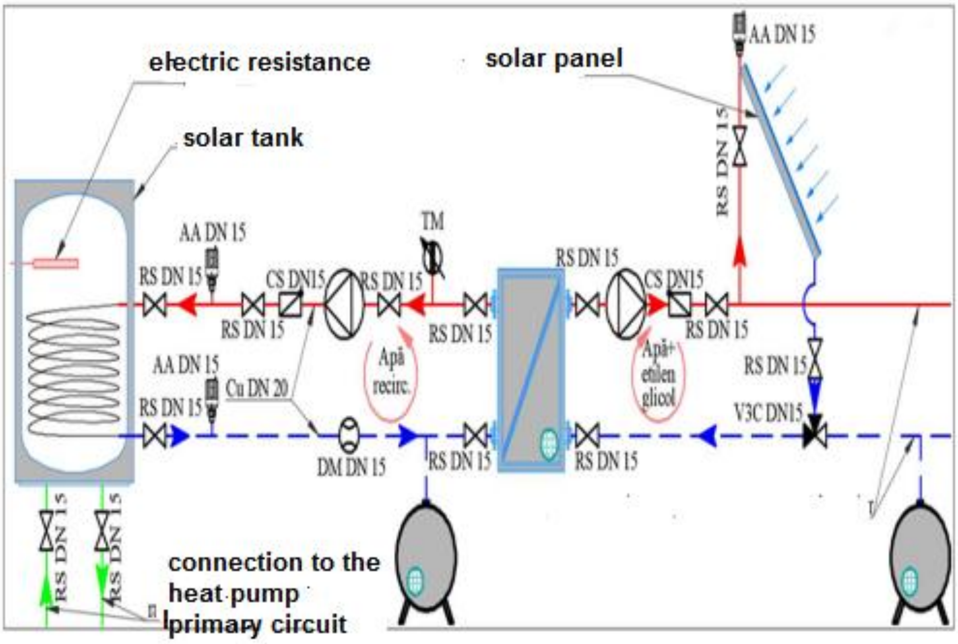

Fig. 5 Solar system connected to a heat pump soil – water according with [13]

In Fig 5. We present o solution describe in [13] (Bulmez M.) about how to increase the soil thermal capacity with solar energy. We have a solar system and a heat exchanger, on the wright side we have a tank connected to primay circuit of heat pump.

3. CONCLUSIONS

The geothermal heat exchangers are studies by many researchers.Many designers in buildings services design heating systems to heat the buildings using heat pumps coupled to soil. The question is what happen with the system after 1-2-3 years in exploitation. The designers should thing how to regenerate the soil. The solutions must be describe in technical project from de beginning. The solutions presented above will assure the energy in soil almost 100% when the pump don't work and aproximative 20 % from energy deliver to the buildings when the pump work. Because is a European Directive about how we use the renewable energy is important to find solutions for maintenance the all system.

The main conclusion of what we propose is that we need external energy to be supplied to the soil from auxiliary sources, the installment depth to the horizontal thermal collector is n important because of the variation of temperature of soil at surface.The installment of horizontal thermal collector is necessary to be made at min1.2 m.depth.

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