Geothermal Heat Pump Systems

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Abstract- *A geothermal heat pump (ground source heat pump) is a central heating and/or cooling system which transfers heat to or from the ground. Earth is used as a heat source (in the winter) and a heat sink (in the summer). The shallow ground temperature is more stable than the ambient air. This design takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems, and may be combined with solar heating to form a geosolar system with even greater efficiency. There is no effect of Geothermal energy on ecology and it won't cause environmental pollution.* CO_2 *emission is also being reduced to high extend. Coefficient of performance (COP) of GSHP system is high i.e. 3 to 6. Installation costs are higher than for conventional systems, but the return on investment (ROI) is less i.e. from 3 to 10 years. The ground source heat pumps are the most energy-efficient, environmentally clean, and cost-effective space conditioning systems. GSHP systems have larger lifespan than that of conventional heating and cooling systems. The geothermal heat pump can be installed in small residential and office buildings, shopping malls and stores etc. In coming years, geothermal heat pump will play an important role in reducing emission of* CO_2*, global warming and saving conventional energy sources.*

Keywords- COP, Geothermal heat pump, Geosolar systems, Heat source and sink,Shallow ground temperature

I. INTRODUCTION

Heat normally flows from a warmer medium to a colder one. Heat is being removed from the place to be cooled in summer and rejected to the ground. In the heating mode the process is reversed and the heat is extracted from the hot ground and released to the colder indoor air. Geothermal heat pumps is a sustainable technology, as it reclaims and recycle thermal energy from the earth. There are various types of GSHP systems which are distinguished by the modes of heat exchanging methods with the ground. Ground source heat pumps have gone beyond normal thermal efficiencies and they also produce zero emissions locally. Carbon emission reduction is so high that installing a 3 tons system is equal to planting 1 acre of trees or taking 2 cars off the road.[1]

A system to supply useful or final energy through ambient air and shallow geothermal energy utilisation generally consists of three system elements:

- Heat source system that withdraws energy from ambient air and near-surface ground.
- Heat pump essential for increasing the temperature and
- Heat sink where the heat is utilised.[2]

Principle:

A ground source heat pump system uses natural heat from underground by circulating antifreeze mixture through it. The temperature of antifreeze mix is increased for heating of home or hot water. On the other side heat is absorbed at a constant low temperature by the evaporating refrigerant (i.e. energy from the ambient air and/or the near-surface ground). Heat is transferred from this cold heat source to the refrigerant, which is at even more low temperature. Afterwards pressure is increased of the evaporated refrigerant by a compressor. This leads to an increase in temperature caused by the Joule-Thomson effect and the almost isentropic and non-isenthalpic compression. At this higher pressure and temperature level, heat is discharged in a condenser to the heat source that is to be heated up. Again heat flows from a high to a slightly lower temperature level. During cooling the heat is taken from the place to be cooled and rejected to the cold ground[3].

Working:

The purpose of a heat pump is to absorb low grade heat in one place where it is plentiful, then to transport, concentrate and release it to another location, where it can be used for space and/or water heating. The ground absorbs low grade solar energy by means of direct sun light and rain. A year round temperature is around 8 to 12^{0}C.

A cold water and antifreeze mix is pumped through the ground within a series of energy absorbing pipes known as ground arrays. As heat naturally flows from warmer to cooler places, the antifreeze mix circulating is constantly warmed by the ground low grade heat. Having increased in temperature the antifreeze mixture is fed into a heat exchanger called the evaporator. Within the secondary sealed side of the evaporator heat exchanger is a refrigerant which acts heat transfer fluid. When the water antifreeze mixture enters the evaporator, the energy absorbed from the ground is transferred into the refrigerant which begins to boil and turn into a gas. The refrigerant never physically mixes with the water antifreeze mixture, they are separated like sandwich layers by the plates of the heat exchangers which permits the heat transfer. This gas is then fed into a compressor. The pressure of the refrigerant gas is increased in a compressor, which makes the gas temperature rise. The hot refrigerant gas then flows to the second heat exchanger called a condenser which features identical set of heat transfer plates. The condenser delivers water hot enough to serve the space heating system and if required the properties hot water needs. Having transferred it's heat the refrigerant gas reversed to a liquid. This liquid is then passed through an expansion valve at the end of the cycle to reduce the pressure and temperature, ready to commence the cycle all over again.

During cooling the process is simply reversed. Heat is extracted out of the indoor air, transferred to the cold refrigerant and then rejected into the cold earth or discharged to water source.

Some geothermal units are designed for hydronic applications like a radiant floor installation. These units warm water instead of conditioning the air. The warm water is circulated through a series of pipes, usually embedded in the floor to provide exceptional heating comfort, regardless of whether the unit is heating or cooling it simply transfers heat energy from one location to another.

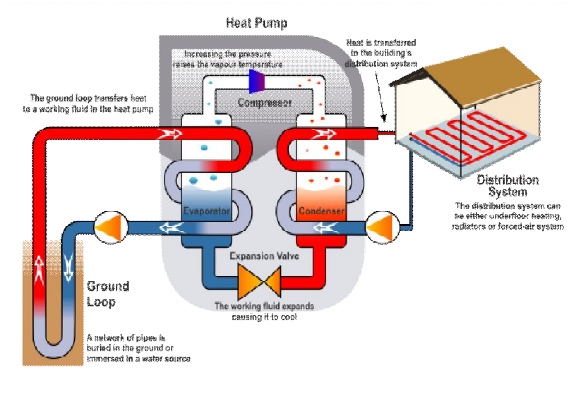


Fig.1: GSHP system

Antifreeze mixes used in GSHP:

- Ethanol (denatured alcohol, ethyl alcohol)
- Ethylene glycol (car antifreeze)
- Propylene glycol
- Calcium chloride

Evaluating site for geothermal heat pump:

- GEOLOGY

In geology the composition and properties of the soil and rock which can affect heat transfer rates which are required while designing a ground loop.[5]

- HYDROLOGY

Ground and surface water availability plays vital role in deciding the type of ground loop to be used. Factors such as depth, volume, and water quality, bodies of surface water can be considered as source of water for an open-loop system, or as a repository for coils of piping in a closed-loop system.[5]

- LAND AVAILABILITY

The amount and layout of the land, the landscaping, and the location of underground utilities or sprinkler systems also contribute to the system design.[5]

Principal types of ground source heat pumps:

- **Closed Loop Systems**

Earth is the major medium for energy transfer. The water and antifreeze mixture is circulated to transfer heat between the ground and antifreeze mix. [3]

- Open Loop Systems

In open loop systems, groundwater is abstracted at ambient temperature from the ground, passed through a heat pump before being re-injected back into the ground or discharged at the surface. Hence, no close loop is formed. [3]

Furthermore, the heat exchangers have different configurations:

1. Horizontal Heat Exchanger

Horizontal heat exchangers are installed in trenches excavated by trenching machines, backhoes, or excavators. In trenches single or multiple-pipe arrangements can be done. The cost of horizontal systems is less. As this does not require special skills and equipment and there is also less uncertainty in subsurface site conditions. The disadvantages of horizontal ground coupling are, it requires high land area, its limited potential for heat exchange with the groundwater, and the extensive temperature swings are being faced at the typical burial depths.

An alternate method of installing a horizontal heat exchanger is the "slinky" method. The coils of plastic piping are spread out in a spiral pattern resembling a deformed slinky toy. Uniform coil spacing is obtained by using fixtures.[5]

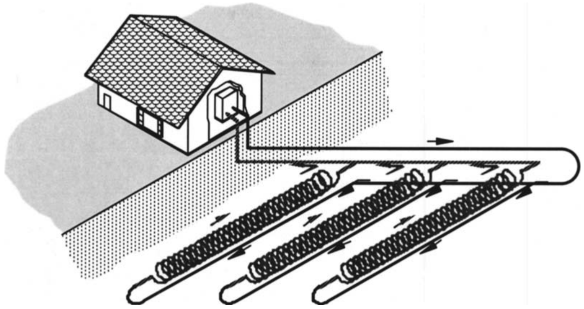


Fig.2: Horizontal slinky-ground coupled heat pump system.

2. Vertical Heat Exchanger:

Vertical heat exchangers are installed by drilling boreholes into the ground and inserting a "u-tube" into the borehole. In low land area availability vertical heat exchangers are preferred. Advantages of vertical ground coupling are: Stable, deep soil temperatures with greater potential for heat exchange with ground water, and adaptability to most sites. Vertical ground-coupling's disadvantages are initial high cost, problems in some geological formations and the need of a proficient driller and installer.[5]

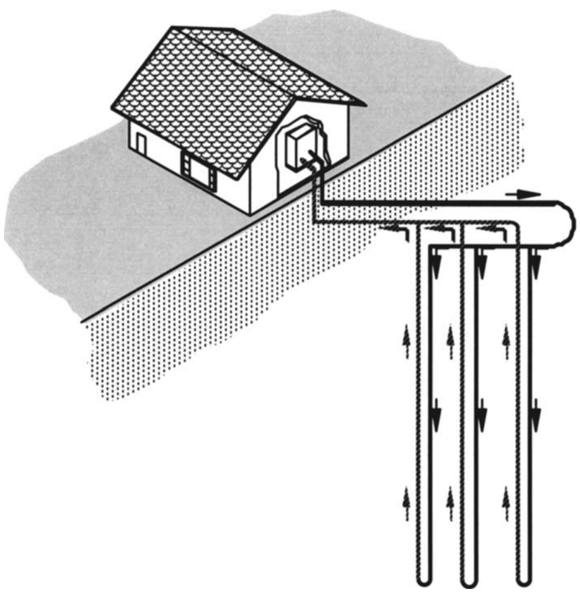


Fig. 3: Vertically ground -coupled heat pump system

3. Ground water heat pump:

These systems exchange heat with the water bodies without physically mixing with water. These systems have the lowest installed cost in most cases, especially in larger applications. However, their use is dependent on the availability of ground water and water quality. But for larger applications, water quality is not as much of an issue, as heat exchangers isolate the heat pumps from the ground water. Averting the contact between the ground water and the atmosphere (i.e., oxygen) is paramount to eliminating problems with GWHP systems.[5]

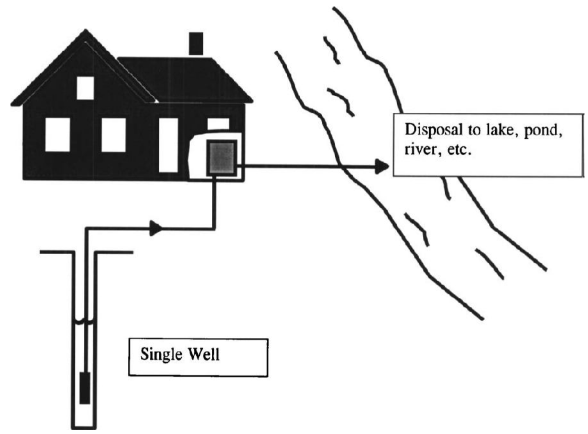


Fig.4: Ground water heat pump system.

This is the most economical system because ground water is extracted from wells and reinjected at separate wells, the entire cost of developing the well system for a GWHP would be at very less expenses.

4. Surface water heat pump:

SWHP systems use surface water bodies to extract and discharge the heat. In some instance this may be done directly by piping water from the water body to and from the heat pump using special purpose plastic pipes, submerged in the water body. This type has been proposed or has seen limited application. In this type ground water is taken from and returned to the same well with normally a fraction being extracted and not returned to the well. The water extracted is usually consumed for domestic use. Net extraction of water from the well forces new water to flow in, thus allowing "thermal regeneration" of the well. [5]

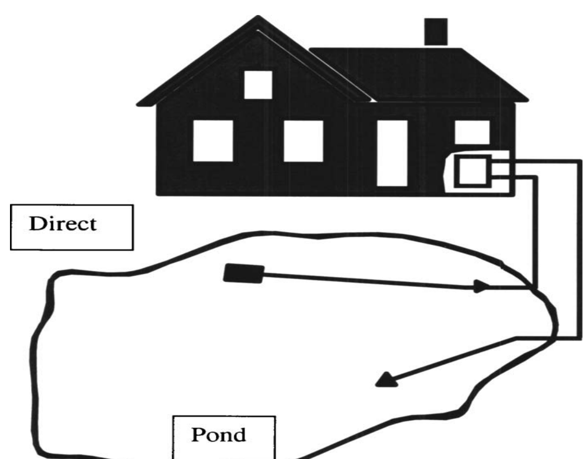


Fig.5: Direct surface water heat pump system.

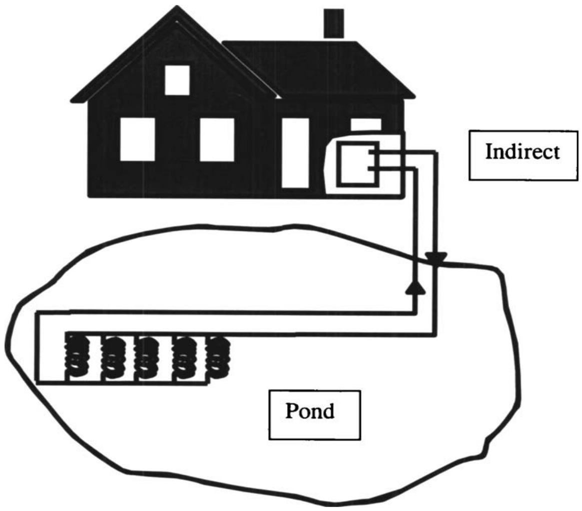


Fig.6: Indirect surface water heat pump system.

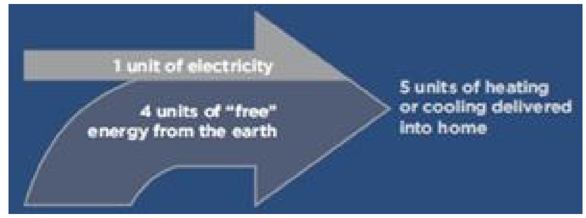
- **Material used:**

Flexible high-density polyethylene plastic pipes are used for GSHP loop system. These joints are heat fused, so 100% leak proof joints are produced. Due to HDPE pipe's versatility, flexibility, durability, leak-proof fusion joints, and ease of use, it has become a key component in the success of Ground Source Heat Pumps. High Density Polyethylene (HDPE) is optimal for geothermal heat pump systems due to its ductility, low temperature impact resistance, permanent flexibility and temperature versatility.

Reliability of this structure is very high, said to be more than 150 years since HDPE has slow degradation, good chemical resistance and heat fusion provides great sealed loop.

Advantages of GSHP:

- Ground Source Heat Pumps save money. Heat pumps are much cheaper to run than direct electric heating systems.
- Heat pumps demand much less work than biomass boilers because of automation.
- Heat pumps save space, as here are no fuel storage requirements.
- As there is no combustion involved and no emission of potentially dangerous gases, it is safe.
- GSHPs require less maintenance than combustion based heating systems. They also have a longer life than combustion boilers. The ground heat exchanger element of a ground source heat pump installation has a design life of over 50 years.
- Heat pumps save carbon emissions. Unlike burning oil, gas, LPG or biomass, a heat pump produces no carbon emissions on site (and no carbon emissions at all, if a renewable source of electricity is used to power them).
- Heat pumps can also provide cooling in summer, as well as heating in winter.
- A well designed ground source heat pump system is likely to increase the sale value of your property.



Disadvantages of GSHP:

- GSHP systems are more expensive to install than air source heat pump systems because of the need to install ground heat exchangers.
- Problem arise with GSHP is the installation is poorly designed.

II. CONCLUSION

The US Environmental Protection Agency (EPA) has called ground source heat pumps the most energy-efficient, environmentally clean, and cost-effective space conditioning systems available. Geothermal heating systems can replace fossil fuel heating systems in particular areas. Thus, reducing emission of CO_2 to greater extend. Greenhouse gas emissions associated with the use of a geothermal heat pump are 55 to 60 percent lower than those from a standard air-source heat pump. Annual cost for common heating purposes can be reduced by more than 60%. All in all geothermal heat pump is a long lasting, efficient way to heat or cool home or workplace.

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